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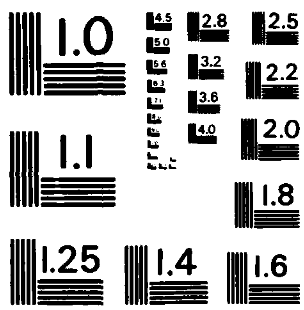

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Structures Technical Memorandum 344 (Supplement)

REPORT ON A VISIT TO THE U.S.A. DURING JANUARY 1982 RELATING TO THE EFFECT OF TURBULENCE AND OTHER METEOROLOGICAL HAZARDS ON AIRCRAFT FLIGHT

Douglas J. SHERMAN

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REPORT ON A VISIT TO THE U.S.A. DURING JANUARY 1982 RELATING TO THE EFFECT OF TURBULENCE AND OTHER METEOROLOGICAL HAZARDS ON AIRCRAFT FLIGHT

by

Douglas J. SHERMAN

SUMMARY

In January, 1982 the author visited the United States to attend and present a paper at the 12th Conference on Severe Local storms in San Antonio Texas. This report highlights certain aspects of that conference and details other discussions held both before and after the conference with the NOAA Environmental Research Laboratories, the FAA, the NASA Langley Research Centre, and the National Severe Storms Laboratory. This supplement contains appendices 4 to 16 of the report.

POSTAL ADDRESS: Chief Superintendent, Aeronautical Research Laboratories, P.O. Box 4331, Melbourne, Victoria, 3001, Australia.

SLIDE 1. AWS SHIELD.

SLIDE 2. MILITARY APPLICATIONS OF METSAT DATA.

GOOD MORNING/AFTERNOON LADIES AND GENTLEMEN. I'M AL KAEHN, COMMANDER OF THE AIR WEATHER SERVICE (AWS), AND THIS MORNING/AFTERNOON I WOULD LIKE TO GIVE YOU SOME OF MY THOUGHTS ON THE MILITARY APPLICATIONS OF METSAT DATA AND, IN PARTICULAR, THE EVOLUTION OF AWS's USE OF THE DEPARTMENT OF DEFENSE METSAT. THE POLAR-ORBITING DEFENSE METEOROLOGICAL SATELLITE PROGRAM OR DMSP, ORIGINALLY KNOWN AS DATA ACQUISITION AND PROCESSING PROGRAM, OR DAPP.

I WILL FOCUS ON OUR METSAT USE AT AIR FORCE GLOBAL WEATHER CENTRAL (AFGWC), OUR CENTRALIZED FACILITY, AND BY OUR FIELD UNITS DEPLOYED AROUND THE WORLD. IN ADDITION, I'LL POINT OUT SOME EXAMPLES OF THE DOD MISSION PAYOFFS DMSP HAS PROVIDED IN THE PAST, AND SOME OF OUR IDEAS FOR FUTURE DMSP ENHANCEMENTS.

SLIDE 3. AWS MISSION.

THE PRIMARY MISSION OF AWS IS TO SUPPORT AIR FORCE AND ARMY COMBAT OPERATIONS. IMPORTANT KEYS TO SUCCESSFUL COMBAT OPERATIONS INCLUDE TARGET DETECTION, IDENTIFICATION, TRACKING, AND DESTRUCTION. IN MODERN WARFARE, THE PRESENCE OR ABSENCE OF CLOUDS DIRECTLY IMPACTS THE ABILITY TO SUCCESSFULLY AND ECONOMICALLY PERFORM THESE MISSIONS, AND WITH THE RECENT DEVELOPMENT OF EXTREMELY EXPENSIVE CLOUD-SENSITIVE WEAPONS SYSTEMS (SUCH AS TV, IR, AND LASER-GUIDED BOMBS AND MISSILES), THE ACCURACY OF CLOUD INFORMATION ASSUMES AN EVEN GREATER ROLE.

SLIDE 4. DATA SOURCES.

AWS USES ALL AVAILABLE DATA TO SATISFY MISSION REQUIREMENTS. PEACETIME CLOUD-DATA SOURCES INCLUDE THE DEFENSE METEOROLOGICAL SATELLITE PROGRAM, NOAA POLAR AND GEOSTATIONARY SATELLITES, WORLDWIDE SURFACE AND UPPER AIR DATA, AND FOREIGN GEOSTATIONARY METSATS. HOWEVER, DURING WARTIME ONLY DATA SOURCES TOTALLY UNDER DOD CONTROL CAN BE RELIED ON. OF THE DATA SOURCES I JUST MENTIONED, ONLY ONE, DMSP, SATISFIES THIS CONDITION.

SLIDE 5. DMSP MISSION.

IN THIS REGARD, THE MISSION OF THE DMSP IS TO PROVIDE, AT ALL LEVELS OF CONFLICT, GLOBAL ENVIRONMENTAL DATA TO SUPPORT WORLDWIDE DOD OPERATIONS. THIS MISSION DEMANDS AT LEAST TWO OPERATIONAL SPACECRAFT ON ORBIT AT ALL TIMES, WITH THE SENSOR COMPLEMENT AND ORBIT TIMES SELECTED TO PROVIDE THE MAXIMUM ENVIRONMENTAL SUPPORT TO MILITARY DECISIONMAKERS.

SLIDE 6. DMSP HISTORY.

THE DMSP HISTORY HAS BEEN ONE OF CONSTANT EVOLUTION. THE SYSTEM WAS ORIGINALLY CONCEIVED AND DESIGNED IN THE 1960's TO SATISFY IMPORTANT, SPECIFIC MILITARY REQUIREMENTS. THE EARLY VEHICLES CARRIED VIDECON CAMERAS PROVIDING ONLY IR AND VISUAL CLOUD IMAGERY. SINCE ITS INCEPTION, A CORNERSTONE DMSP REQUIREMENT WAS TO PUT DATA IN THE HANDS OF THE MILITARY DECISIONMAKERS AS SOON AS POSSIBLE. THEREFORE, DMSP WAS CONFIGURED TO PROVIDE DATA IN TWO WAYS: THE RECORDED AND DIRECT READOUT DATA MODES.

SLIDE 7. DMSP HISTORY.

IN THE RECORDED DATA MODE, DATA ARE RECORDED ABOARD THE SPACECRAFT AND DOWNLINKED TO READOUT SITES AT LORING AFB, MAINE, AND FAIRCHILD AFB, WASHINGTON. IN THE EARLIER DAYS, THE DATA WERE PASSED TO AFGWC AT OFFUTT AFB, NEBRASKA, BY LANDLINES. TODAY THEY ARE PASSED BY A COMMUNICATIONS SATELLITE. IN RECENT YEARS THE SYSTEM HAS INCLUDED A COMSAT DOWNLINK TO FLEET NUMERICAL OCEANOGRAPHY CENTER IN MONTEREY, CALIFORNIA, AND AN ADDITIONAL READOUT SITE AT KAENA POINT, HAWAII.

THOUGH THE ROUTING OF THE RECORDED DATA HAS NOT CHANGED TOO MUCH DURING THE LIFE OF THE DMSP SYSTEM, THE TYPES OF RECORDED DATA HAVE INCREASED SIGNIFICANTLY. THE FIRST MISSION SENSOR OTHER THAN THE CLOUD IMAGER WAS A GAMMA RADIATION DETECTOR FLOWN IN 1971. THE DMSP MISSION EXPANDED TO INCLUDE AN ADDITIONAL TROPOSPHERIC AND ITS FIRST IONOSPHERIC MISSION IN NOV 1972 WITH THE LAUNCH OF A VEHICLE WITH A TROPOSPHERIC TEMPERATURE SOUNDER AND A PRECIPITATING ELECTRON SPECTROMETER. THE FIRST OPERATIONAL LINESCAN SYSTEM, OR OLS, A VASTLY IMPROVED SYSTEM FOR CLOUD SENSING, WAS FLOWN IN SEPTEMBER OF 1976.

THE INITIAL TRANSPORTABLE TERMINALS, USING THE DIRECT READOUT DATA, SUPPORTED AIR FORCE AND ARMY COMMANDERS AROUND THE WORLD. THE NAVY CAME ON BOARD WITH THEIR REQUIREMENT FOR DIRECT READOUT DATA IN 1971, INSTALLING THEIR FIRST SHIPBOARD CAPABILITY ON THE USS CONSTELLATION.

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(OPTIONAL ANECDOTE. AS FOLLOWS: DMSP ANTENNAS WERE LOCATED MIDSHIP BELOW AND ON EITHER SIDE OF THE FLIGHT CHECK. IN TWO SEPARATE INCIDENTS (72 AND EARLY 73), AIRCRAFT (AN A-7 AND AN F-4) BROKE THE ARRESTING CABLE ON LANDING. THE CABLE WRAPPED AROUND THE DMSP ANTENNA (DESTROYING IT IN EACH CASE) AND THE BARRIER HELD. THEREFORE, DMSP (WEATHER) COULD BE CONSIDERED TO HAVE SAVED TWO AIRCRAFT).

TODAY, DIRECT READOUT DATA CONTINUE TO PROVIDE DIRECT CLOUD IMAGERY SUPPORT TO ARMY AND AIR FORCE FIELD COMMANDERS AND NAVY OPERATIONS AFLOAT.

SLIDE 8. UNIQUE DMSP CAPABILITIES.

DMSP CONTINUES TODAY TO GROW AND CHANGE TO MEET DOD REQUIREMENTS. UNIQUE CAPABILITIES ARE DOD COMMAND AND CONTROL UNCONSTRAINED BY EXTERNAL AGREEMENTS, THE CAPABILITY OF ENCRYPTED COMMUNICATIONS INTO COMBAT ZONES, ORBITS AND SENSORS SPECIFICALLY SELECTED TO OPTIMIZE DOD REQUIREMENTS SATISFACTION, FLEXIBILITY TO ALTER COVERAGE TO RESPOND TO RAPIDLY CHANGING DOD SUPPORT NEEDS, AND A SYSTEM DESIGNED TO MINIMIZE DELAY IN READOUT OF CRITICAL RECORDED DATA.

IN ADDITION, TODAY'S DMSP POSSESSES OTHER CHARACTERISTICS EXTREMELY VALUABLE TO AWS: ITS CONSTANT CROSS SCAN HIGH RESOLUTION IMAGING IS VALUABLE FOR SNOW/CLOUD DISCRIMINATION AND "BLACK STRATUS" ANALYSIS. ITS LOW LIGHT NIGHTTIME CAPABILITY IS VALUABLE IN DETERMINING THE MAGNITUDE AND EXTENT OF THE AURORAL OVAL, AND FINALLY, IT HAS A FULL COMPLEMENT OF IONOSPHERIC SENSORS CRITICAL TO MANY DOD SYSTEMS OPERATING IN OR THROUGH THE NEAR EARTH ENVIRONMENT.

SLIDE 9. AIR FORCE DMSP USAGE.

IN THE NEXT FEW MINUTES I WILL AMPLIFY ON THE USE OF RECORDED AND DIRECT READOUT DMSP DATA BY THE AIR FORCE. BRIEFLY, RECORDED DMSP DATA RECEIVED AT AFGWC RESULTS IN DOCUMENTED SAVINGS OF HUNDREDS OF MILLIONS OF DOLLARS PER YEAR. RECORDED DATA ARE USED TO SUPPORT WORLDWIDE OPERATIONS SUCH AS THE RAPID DEPLOYMENT JOINT TASK FORCE, HURRICANE/TYPHOON POSITIONING, AERIAL REFUELING AND STRATEGIC AIR COMMAND AIRCRAFT RECONNAISSANCE MISSIONS. DIRECT READOUT DATA ARE USED BY METEOROLOGISTS IN FORWARD AREAS TO SUPPORT BATTLEFIELD COMMANDERS CONDUCTING COMBAT OPERATIONS. CRITICAL TO THE EFFECTIVENESS OF BOTH CAPABILITIES, ESPECIALLY RECORDED DATA, IS SPACECRAFT COMMAND AND CONTROL.

SLIDE 10. COMMAND AND CONTROL.

TO MEET RIGID OPERATIONAL SUPPORT TIMELINES, COMMAND AND CONTROL MUST BE RESPONSIVE. THEREFORE, THE SPACECRAFT GROUND COMMAND AND CONTROL SYSTEM IS COLLOCATED WITH THE AFGWC. IF WE NEED DMSP DATA THAT ARE NOT NORMALLY COLLECTED, TO SATISFY A SHORT-NOTICE REQUIREMENT, NEW SOFTWARE COMMANDS CAN BE GENERATED AND IMPLEMENTED WITHIN 6 HOURS THROUGH THE CONTROL READOUT SITES.

SLIDE 11. DMSP DATA FLOW. (RECORDED DATA.)

MILITARY REQUIREMENTS FOR FORECASTS OF ICING, TURBULENCE, SEVERE WEATHER, FIELDS OF SMALL CELL CUMULUS AND SNOW/CLOUD DISCRIMINATION DEMAND IMMEDIATE MANUAL APPLICATION OF HIGH-QUALITY 0.3 AND 1.5 NM RESOLUTION VISUAL AND IR IMAGERY DATA. THESE DATA ARE DISPLAYED ON "HARD COPY" TRANSPARENCIES FOR USE BY FORECASTERS AT AFGWC. (AFTER THE DATA ARE NO LONGER OPERATIONALLY USEFUL, THE TRANSPARENCIES ARE ARCHIVED AT THE UNIVERSITY OF WISCONSIN FOR PUBLIC USE.) AT THE SAME TIME, THE DATA FLOW INTO A COMPLETELY AUTOMATED PROCESSING SYSTEM.

SLIDE 12. AUTOMATED PROCESSING SYSTEM.

THE TELEMETRY DATA ARE SPLIT OFF FOR COMMAND AND CONTROL PURPOSES.

ATMOSPHERIC AND SPACE ENVIRONMENTAL DATA ARE STRIPPED OUT AND PROCESSED BY SENSOR-UNIQUE SOFTWARE. TEMPERATURE SOUNDER DATA ARE CURRENTLY USED GLOBALLY IN THE STRATOSPHERE. THEY ARE ALSO USED IN THE TROPOSPHERE--BOTH IN THE SOUTHERN HEMISPHERE, AND DATA-SPARSE OCEAN AREAS IN THE NORTHERN HEMISPHERE.

UNIQUE SPACE ENVIRONMENTAL DATA ARE PROVIDED BY THE PRECIPITATING ELECTRON SPECTROMETER, THE PLASMA MONITOR, AND THE VISUAL CLOUD SENSOR. THE VISUAL DATA AND THE ELECTRON SPECTROMETER LOCATE THE AURORAL OVAL--IMPORTANT TO FORECASTS FOR HIGH FREQUENCY RADIO COMMUNICATIONS IN POLAR REGIONS AND THE HIGH LATITUDE EARLY WARNING AND TRACKING RADAR NETWORK IN NORTH AMERICA AND EUROPE. THE PLASMA MONITOR PROVIDES IN-SITU ELECTRON DENSITIES--ESSENTIAL TO SPACE SYSTEM EPHEMERIS CALCULATIONS AND ANOMALY INVESTIGATIONS AS WELL AS TRANSIONOSPHERIC PROPAGATION FOR THE SPACE DETECTION AND TRACKING SYSTEM.

VISUAL AND IR IMAGERY ARE MAPPED INTO A SATELLITE GLOBAL DATA BASE, A DIGITAL-DATA BASE WITH A 3NM RESOLUTION. THIS DATA BASE IS CONSTANTLY UPDATED BY CONTINUOUS ON-LINE PROCESSING OF THE IMAGERY AND IS AVAILABLE IN VISUAL AND IR DISPLAY FOR BOTH HEMISPHERES.

SLIDE 13. SGDB APPLICATIONS.

UNDER THE SHARED METSAT DATA CONCEPT, THE SATELLITE GLOBAL DATA BASE IS PLANNED TO BE PROVIDED TO NOAA/NESS AND FNOC. WE APPLY THE AUTOMATED DATA BASE IN THREE WAYS:

(1) HIGH QUALITY DISPLAYS ARE SENT BY DIGITAL FACSIMILE TO AIR FORCE COMMAND AND CONTROL CENTERS. THE DATA ARE ALSO RELAYED TO A MYRIAD OF OTHER GOVERNMENT AGENCIES.

(2) SECOND, DISPLAYS ARE USED AS LARGE OVERLAYS FOR FORECAST APPLICATIONS WITHIN AFGWC.

(3) THE THIRD APPLICATION IS UNIQUE TO AWS. AFGWC IS A PIONEER IN USING COMPUTERS TO BLEND SATELLITE DATA WITH OTHER DATA AND BUILD AUTOMATED CLOUD ANALYSES WHICH, IN TURN, ARE USED TO INITIALIZE AUTOMATED CLOUD FORECASTS.

SLIDE 14. CLOUD ANALYSIS MODEL. THE AUTOMATED CLOUD ANALYSIS MODEL INTEGRATES THE VISUAL AND IR IMAGERY, AND REMOTE SENSED TEMPERATURE SOUNDINGS, ALONG WITH CONVENTIONAL OBSERVATIONS, TO CREATE A 25 NM RESOLUTION THREE DIMENSIONAL CLOUD ANALYSIS. DATA COVERING HIGH PRIORITY AREAS ARE ANALYZED IMMEDIATELY UPON RECEIPT, WHILE THE NORMAL GLOBAL ANALYSIS IS ACCOMPLISHED EVERY THREE HOURS. THE PROCESS IS TOTALLY AUTOMATED WITH THE EXCEPTION THAT ANALYSIS

IN HIGH PRIORITY AREAS CAN BE MANUALLY MODIFIED IF NEEDED. WE HAVE NOW BEGUN WORK TO DEVELOP A REAL-TIME CLOUD ANALYSIS MODEL THAT WILL ANALYZE ALL SATELLITE DATA IMMEDIATELY UPON RECEIPT. THUS THE REALTIME ANALYSIS WILL ALWAYS INCLUDE THE MOST CURRENT SATELLITE DATA.

<u>SLIDE 15</u>. CLOUD FORECAST MODEL.
THE CLOUD ANALYSIS INITIALIZES THE FINAL STEP IN THE PROCESS--THE AUTOMATED CLOUD FORECAST MODEL. IT IS PROCESSED EVERY THREE HOURS AND FORECASTS CLOUD COVER AND PRECIPITATION OUT TO 48 HOURS IN THE NORTHERN HEMISPHERE AND 24 HOURS IN THE SOUTHERN HEMISPHERE.

<u>SLIDE 16</u>. SUMMARY OF RECORDED DATA MODE CAPABILITIES.
AS YOU CAN SEE, RECORDED DATA ARE USED TODAY AT AFGWC IN A COMPLEX SYSTEM RELYING ON A CONSIDERABLE AMOUNT OF COMPUTER HARDWARE AND SOFTWARE. YET, THE SYSTEM IS EXTREMELY RELIABLE. OVER 95% OF THE DMSP DATA ARE ROUTINELY PROCESSED THROUGH THE SYSTEM AND ARE USED IN THE FORECAST MODELS. NOT ONLY DO UNITS IN THE FIELD RECEIVE ANALYSIS AND FORECAST PRODUCTS FROM AFGWC TO SUPPORT TACTICAL REQUIREMENTS, BUT ALSO THEY HAVE ACCESS TO DMSP DIRECT READOUT DATA.

<u>SLIDE 17.</u> DMSP DIRECT READOUT
THE DMSP DIRECT READOUT DATA CAPABILITY SATISFIES DOD REQUIREMENTS FOR WORLDWIDE, RESPONSIVE, SECURE, HIGH RESOLUTION METSAT INFORMATION. THE SYSTEM IS COMPLETE AND SELF-SUFFICIENT, AND THE TRANSPORTABLE TERMINALS HAVE THEIR OWN POWER SUPPLY AND DATA PROCESSING CAPABILITY. IN THIS MODE, DMSP PROVIDES TIMELY VISUAL AND INFRARED IMAGERY DIRECTLY TO TRANSPORTABLE TERMINALS COLLOCATED WITH BATTLEFIELD COMMANDERS.

SLIDE 18. TACTICAL USES.

THROUGH THESE FEW EXAMPLES: SUPPORT OF CRITICAL DECISIONS IN VIETNAM; SUPPORT TO U.S. FORCES IN DATA DENIED AREAS--SUCH AS ISRAEL; SUPPORT TO EUROPE WHERE WEATHER DATA WILL BE USED AS A WEAPONS MULTIPLIER; SUPPORT OF U.S. READINESS FORCES SUCH AS REDCOM AND TAC; AND SUPPORT OF U.S. RESOURCE PROTECTION EFFORTS IN THE PACIFIC.....I PLAN TO SHOW HOW WE'VE USED THE DMSP IN THE PAST AND HOW WE'RE CURRENTLY USING IT.

SLIDE 19. TARGET ACQUISITION.

GENERAL MOMYER, AF COMMANDER IN VIETNAM, RELATING HIS EXPERIENCE WITH THE DMSP SYSTEM SAID, "AS FAR AS I AM CONCERNED, THIS (DMSP) WEATHER PICTURE IS PROBABLY THE GREATEST INNOVATION OF THE WAR." WHILE DISCUSSING THE SCHEDULING, TARGETING AND LAUNCHING OF STRIKE MISSIONS AGAINST NORTH VIETNAM, IN HIS BOOK HE WENT ON TO SAY THAT, "WITHOUT THEM (MEANING THE DMSP PHOTOS)...MANY MISSIONS WOULD NOT HAVE BEEN LAUNCHED."

SLIDE 20. COMBAT SUPPORT -- VIETNAM.

THE RESPONSIVENESS OF THE DMSP TO MILITARY REQUIREMENTS WAS FIRST DEMONSTRATED DURING THE EARLY STAGES OF VIETNAM WHEN A SATELLITE WAS LAUNCHED TO SUPPORT OUR BOMBING MISSIONS. AF COMMANDERS IN VIETNAM MAKING GO/NO GO DECISIONS AFFECTING STRIKE MISSIONS USED DMSP BECAUSE IT IS A COMPLETE SYSTEM WITH A TACTICAL READOUT CAPABILITY. THE TACTICAL, OR DIRECT READOUT TERMINAL LOCATED IN SAIGON PROVIDED PROCESSED, ANALYZED PICTURES OF THE WEATHER IN THE VARIOUS TARGET AREAS IN A MATTER OF MINUTES AFTER BEING OBSERVED. THIS INFORMATION WAS USED TO UPDATE AND ADJUST STRIKE TARGETS AND THE LIFE SUSTAINING REFUELING AREAS BASED ON THE CURRENT WEATHER OBSERVED BY THE DMSP.

IN LATE 1970, VERY SPECIFIC WEATHER WAS REQUIRED TO SUPPORT THE MISSION TO EXTRACT U.S. PRISONERS OF WAR FROM A NORTH VIETNAMESE PRISON CAMP. THIS MISSION, THE SON TAY PRISON RAID, WAS SCHEDULED TO COINCIDE WITH THE BREAK IN WEATHER BETWEEN TWO TROPICAL STORMS. CONVENTIONAL WEATHER DATA WERE DENIED AND AN AERIAL WEATHER RECONNAISSANCE FLIGHT MIGHT TIP OFF THE OPERATION. THE NEED FOR SECRECY AND LIMITING THE NUMBER OF PEOPLE WHO KNEW OF OUR INTEREST IN THE WEATHER NEAR SON TAY WAS SATISFIED BY THE OPERATIONAL SECRECY AVAILABLE WITH THE DMSP. THE DMSP DATA, PROVIDED TO THE 7TH AF PLANNERS FROM THE DMSP TACTICAL TERMINAL AT SAIGON WERE CRUCIAL IN IDENTIFYING THE BEST WEATHER WINDOW POSSIBLE TO ACHIEVE THE PRECISION TIMING NECESSARY FOR THIS MISSION, YET MAINTAINING THE SECRECY NECESSARY IN SUCH A SENSITIVE MILITARY OPERATION.

SLIDE 21. CRISIS DATA DENIAL.

GLOBAL WAR IS NOT NECESSARY TO AFFECT THE FREE EXCHANGE OF METEOROLOGICAL DATA AMONG NATIONS. INCREASED LOCAL TENSIONS BETWEEN TWO OR MORE NATIONS CAN CUT THE FLOW OF NECESSARY WEATHER DATA. DURING THE YOM KIPPUR WAR ALL NATIONS IN THE AREA OF CONFLICT STOPPED TRANSMISSION OF STANDARD METEOROLOGICAL DATA OVER CIVIL COMMUNICATIONS CIRCUITS - DESPITE INTERNATIONAL AGREEMENTS TO THE CONTRARY - BECAUSE WEATHER DATA COULD POSSIBLY AID OPPOSITION COMMANDERS IN MAKING MILITARY DECISIONS. EARLY IN THE U.S. RESUPPLY EFFORT OF ISRAEL, LOD AIRPORT AT TEL AVIV WAS CLOSED DUE TO HEAVY FOG AND STRATUS AND OUR RESUPPLY FLOW WAS DISRUPTED. WEATHER DATA FROM THE DMSP ENABLED US TO DETERMINE THE WEATHER PATTERN WAS FRONTAL IN NATURE AND TO ACCURATELY

PREDICT CLEARING, ENSURING EARLIEST POSSIBLE COMPLETION OF THE VITAL AIRLIFT DURING THE INITIAL PHASES OF THE WAR. DURING A EUROPEAN WAR, OUR ENEMIES WILL ALMOST CERTAINLY STOP TRANSMITTING WEATHER DATA. IN ADDITION, OUR ALLIES MAY STOP TRANSMITTING WEATHER DATA BECAUSE OF ITS USEFULNESS TO WARSAW PACT COUNTRIES, AND THE ENCRYPTED DMSP DATA AVAILABLE AT TACTICAL TERMINALS IN EUROPE MAY BE THE ONLY WEATHER DATA OUR EUROPEAN FORCES HAVE TO USE. DURING AUG 79, WE USED DMSP TO SUPPORT OPERATIONS IN NICARAGUA FROM THE TACTICAL TERMINAL AT HOWARD AFB, WHEN CONVENTIONAL DATA WERE NOT AVAILABLE IN NICARAGUA DURING THE OVERTHROW OF THE SOMOZA REGIME.

SLIDE 22. COMBAT DEPLOYMENT.

THE U.S. READINESS COMMAND'S MISSION REQUIRES SHORT NOTICE DEPLOYMENT OF A JOINT TASK FORCE TO VIRTUALLY ANY AREA OF THE WORLD. HIGH RESOLUTION SATELLITE DATA, RESPONSIVE TO THE DEPLOYED MILITARY COMMANDER, ARE OFTEN THE SOLE SOURCE OF WEATHER DATA IN A CONTINGENCY AREA WHERE DATA ARE EITHER SPARSE OR DENIED. IN SUPPORT OF U.S. COMMITMENTS TO NATO, THE U.S. REGULARLY DEPLOYS TACTICAL FIGHTER SQUADRONS FROM U.S. BASES TO DESIGNATED ALLIED AIRFIELDS IN EUROPE. DECISIONS TO LAUNCH, DELAY, OR CHANGE REFUELING AREAS; NOT ONLY FOR THE FIGHTER AIRCRAFT, BUT ALSO FOR THE TANKER AIRCRAFT NEEDED FOR REFUELING, ARE OFTEN MADE SOLELY BASED ON THE HIGH RESOLUTION DATA AVAILABLE FROM THE DMSP.

SLIDE 23. DOD RESOURCE PROTECTION.

A DMSP TACTICAL TERMINAL, AS WELL AS RECORDED DATA FROM AFGWC, PROVIDE COVERAGE NECESSARY FOR THE AIR FORCE WEATHER SATELLITE

SUPPORT TO THE JOINT TYPHOON WARNING CENTER (JTWC) LOCATED AT GUAM IN THE PACIFIC. JTWC PROVIDES TYPHOON WARNINGS AND ACCURATE FIXES OF STORM POSITIONS AND ALSO PROVIDES DOD WITH RESOURCE-PROTECTION WARNINGS NECESSARY IN THIS PREDOMINANTLY DATA-SPARSE AREA. IN 1978 AND 1979, MORE THAN HALF OF THE JTWC's WARNING IN THE WESTERN PACIFIC WERE BASED ON SATELLITE POSITIONS OF TROPICAL CYCLONES. IN THE INDIAN OCEAN, WHERE AIRCRAFT AND LAND-BASED RADAR WERE NOT AVAILABLE, OVER 95 PERCENT OF THE JTWC's WARNINGS WERE BASED ON SATELLITE FIXES. THIS INFORMATION, REQUIRED BY MILITARY COMMANDERS THROUGHOUT THE PACIFIC, IS ALSO MADE AVAILABLE TO CIVIL AND INTERNATIONAL AGENCIES.

<u>SLIDE 24.</u> FUTURE DMSP--AWS SUPPORT.

THE EXAMPLES I'VE JUST DISCUSSED HIGHLIGHT THE EXTENSIVE USE OF DMSP BY AIR WEATHER SERVICE. LIMITED MILITARY RESOURCES AND CONTINUED TENSIONS WORLDWIDE CALL FOR INCREASED RESPONSIVENESS OF THE DMSP SYSTEM. IN ADDITION, COMMANDERS USING MORE COMPLEX, SOPHISTICATED WEAPONS SYSTEMS WHICH ARE HIGHLY SENSITIVE TO ENVIRONMENTAL FACTORS DICTATE THE FURTHER EXPLOITATION AND EXPANSION OF THE DMSP. TO MEET THESE GROWING OPERATIONAL SUPPORT REQUIREMENTS DURING THE 1980's, WE HAVE PROGRAMMED ADDITIONAL CAPABILITIES FOR THE DMSP.

<u>SLIDE 25.</u> DMSP IMPROVEMENTS.

THE SPACE ENVIRONMENT MISSION WILL BE STRENGTHENED WITH THE ADDITION OF BOTH A TOPSIDE IONOSONDE AND A REFINED PLASMA DENSITY MONITOR FOR DETAILED PROFILES OF ELECTRON DENSITY. THE MICROWAVE IMAGERY WILL ALLOW US TO RECOVER AERIAL EXTENT AND RATES OF

PRECIPITATION OVER THE GLOBE. WE ENVISION THESE DATA WILL GIVE US AN IMPROVED CLOUD ANALYSIS CAPABILITY AND OVER DATA-DENIED AREAS WILL, WHEN COMBINED WITH KNOWLEDGE OF THE TERRAIN, PROVIDE IMPROVED TRAFFICABILITY FORECASTS FOR ARMY COMMANDERS. THIS WILL ALLOW COMMANDERS TO MORE EFFECTIVELY EMPLOY THEIR HEAVY TANKS, TRUCKS, AND ARTILLERY PIECES IN THEIR OVERALL STRATEGY. FINALLY, INCREASED SYSTEM SURVIVABILITY AND RELIABILITY WILL INCREASE THE DMSP UTILITY AT THE AIR FORCE GLOBAL WEATHER CENTRAL. WE PLAN TO IMPROVE THE AUTOMATED IMAGERY-PROCESSING SYSTEM BY INSTALLING INTERACTIVE AND SOFTCOPY DISPLAY CONSOLES TO INCREASE DATA BASE ACCESSIBILITY AND REDUCE CRITICAL PROCESSING TIMELINESS. ALSO, THE CLOUD ANALYSIS MODEL IS BEING IMPROVED SO INCOMING DATA WILL UPDATE THE ANALYSIS CONTINUOUSLY. THEREFORE, CLOUD FORECASTS CAN BE RUN AT ANY TIME USING THE LATEST DATA AVAILABLE.

SLIDE 26. MARK IV TACTICAL DEPLOYMENT.

AF IS CURRENTLY DEPLOYING AN IMPROVED DIRECT READOUT TERMINAL FOR TACTICAL USE. THE MARK IV IS A TOTALLY SELF-SUFFICIENT TACTICAL TERMINAL, TRANSPORTABLE ON C-130 TYPE AIRCRAFT SHOWN ON THE SLIDE AS OPPOSED TO THE LARGER C-5 SIZED AIRCRAFT NEEDED TO AIRLIFT OUR CURRENT TACTICAL TERMINALS.

SLIDE 27. TACTICAL VAN IMPROVEMENTS.

IN THE FUTURE, MULTIPLE SENSOR DATA, SUCH AS MICROWAVE IMAGERY AND ATMOSPHERIC SOUNDER DATA, ARE PLANNED TO BE INCLUDED IN THE DIRECT READOUT MODE. THESE DATA WILL INCREASE THE CAPABILITY OF THE BATTLEFIELD METEOROLOGIST TO PROVIDE THE TACTICAL COMMANDER CRITICAL SUPPORT WHEN CONVENTIONAL WEATHER DATA ARE DENIED. IN

ADDITION, WE PLAN TO INCLUDE A DATA PROCESSING CAPABILITY IN THE FUTURE TACTICAL VAN. THIS SYSTEM WILL BE ABLE TO PROVIDE INSTANTANEOUS UPDATES ON THE WEATHER TO THE TACTICAL COMMANDERS' AUTOMATED SYSTEMS. COMMANDERS WILL THEN BE ABLE TO MAKE IMMEDIATE CHANGES TO TARGETS OR TACTICS MAXIMIZING THE POTENTIAL OF THEIR AUTOMATED COMMAND AND CONTROL SYSTEMS.

SLIDE 28. SUMMARY.

THE DMSP, A SYSTEM RESPONSIVE TO MILITARY REQUIREMENTS, HAS GROWN CONSIDERABLY DURING THE PAST DECADE. THE CLOSE INTERACTION AMONG THE WEATHERMAN AT THE TACTICAL READOUT TERMINAL DIRECTLY SUPPORTING THE TACTICAL COMMANDER, THE AIR FORCE GLOBAL WEATHER CENTRAL BUILDING AND APPLYING ITS WORLDWIDE DATA BASE, AND DEDICATED COMMAND AND CONTROL OF THE ON-ORBIT DMSP SATELLITES HAS PROVIDED A FINELY TUNED MILITARY SYSTEM CAPABLE OF RESPONDING TO NATIONAL SECURITY REQUIREMENTS. IN SHORT, MILITARY METSAT APPLICATIONS HAVE PROVEN TO BE A VITAL SOURCE OF DATA FOR AWS's SUPPORT TO NATIONAL DEFENSE AND WILL CONTINUE TO EVOLVE TO MEET THE CHANGING NEEDS OF MILITARY DECISIONMAKERS.

AWS SHIELD

MILITARY APPLICATIONS OF METSAT DATA

- DOD METSAT - DMSP
- AFGWC
- FIELD UNITS
- DOD PAYOFFS
- FUTURE ENHANCEMENTS

AWS MISSION

PRIMARY MISSION: SUPPORT AIR FORCE AND ARMY COMBAT OPERATIONS

- SUCCESSFUL COMBAT OPERATIONS DEPEND ON TARGET:
  - -- DETECTION
  - -- IDENTIFICATION
  - -- TRACKING
  - -- DESTRUCTION
- NEW WEAPONS SYSTEMS EXTREMELY WEATHER SENSITIVE

DATA SOURCES

USE ALL AVAILABLE DATA TO SATISFY MISSION REQUIREMENTS

- PEACETIME - MANY SOURCES
- WARTIME - DMSP

DMSP MISSION

PROVIDE - AT ALL LEVELS OF CONFLICT - GLOBAL ENVIRONMENTAL DATA TO SUPPORT WORLDWIDE DOD OPERATIONS.

- REQUIRES AT LEAST 2 OPERATIONAL SATELLITES
- SENSOR COMPLEMENT/ORBIT TAILORED TO DOD NEEDS

DMSP HISTORY

EVOLVING SYSTEM

- RESPONSIVE TO MILITARY REQUIREMENTS
- EARLY VEHICLES CLOUD IMAGERY ONLY

DATA TO DESIONMAKER IN MINIMUM TIME

DMSP HISTORY

CONFIGURATION - RECORDED AND DIRECT READOUT

RECORDED DATA EVOLUTION

- DATA FLOW
- SENSOR COMPLEMENT RESPONSIVE TO DOD NEEDS
  - -- TROPOSPHERIC MISSION
  - -- IONOSPHERIC MISSION
  - -- IMPROVED CLOUD SENSOR

DIRECT READOUT EVOLUTION

- INITIALLY AIR FORCE/ARMY USE
- NAVY ON BOARD IN 1971

4-22

UNIQUE DMSP CAPABILITIES

DOD COMMAND & CONTROL

ENCRYPTION

ORBIT OPTIMIZATION

FLEXIBILITY

MINIMIZE READOUT TIMES

CONSTANT CROSS SCAN RESOLUTION

LOW LIGHT NIGHT TIME CAPABILITY

IONOSPHERIC SENSORS

AIR FORCE DMSP USAGE

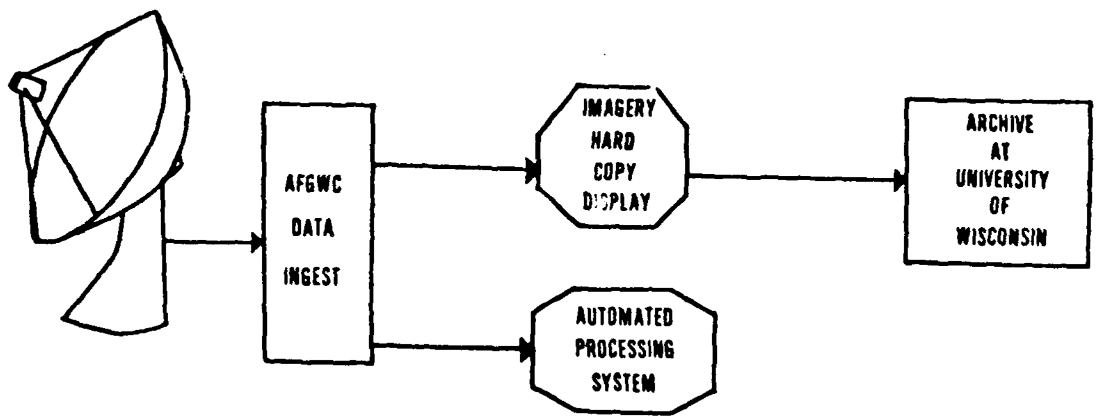
DATA TYPE	LOCATION	MISSION
RECORDED	AFGWC	WORLDWIDE FORECAST SUPPORT
DIRECT	BATTLEFIELD	COMBAT OPERATIONS

COMMAND & CONTROL

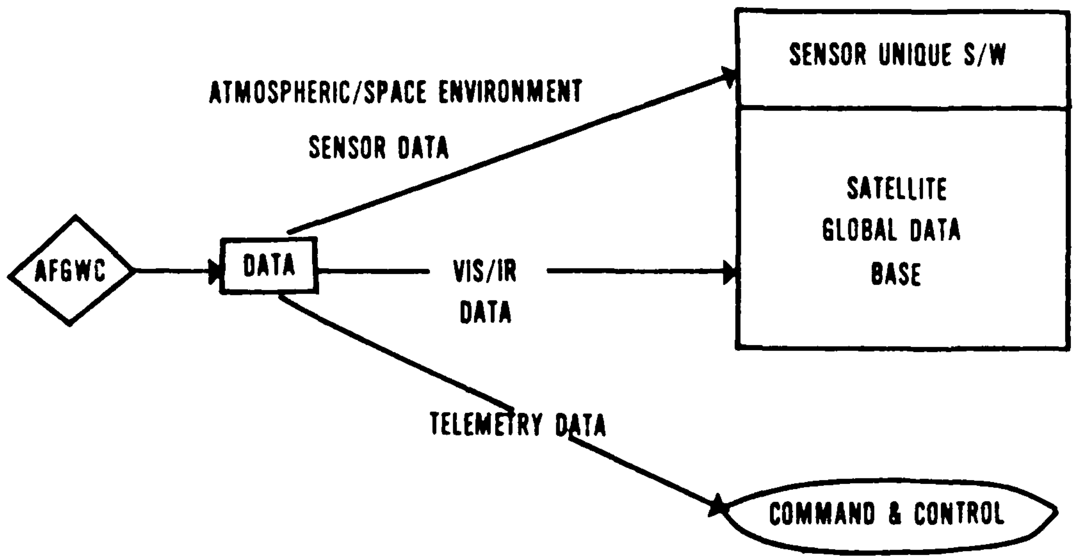
RESPONSIVE - GROUND SYSTEM COLLOCATED WITH AFGWC

CHANGE ON BOARD COMMAND WITHIN 6 HOURS

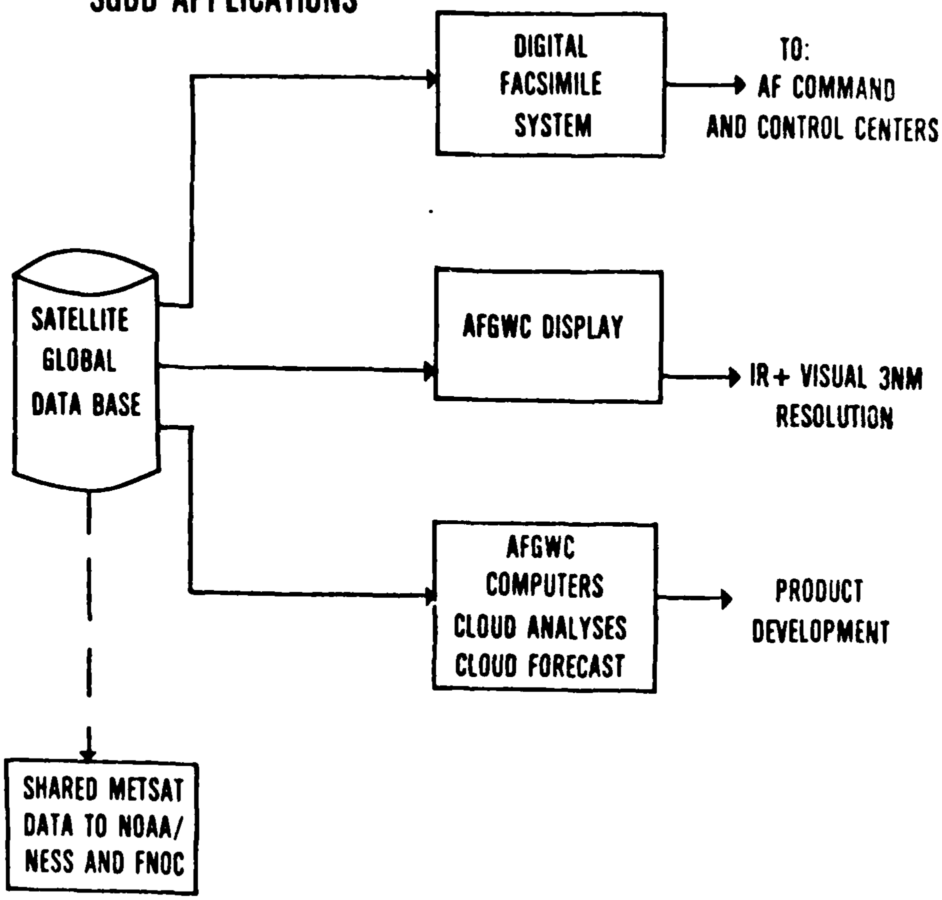
DMSP DATA FLOW (RECORDED DATA)



AUTOMATED PROCESSING SYSTEM



SGDB APPLICATIONS



CLOUD ANALYSIS MODEL

AUTOMATED CLOUD ANALYSIS INTEGRATES

- SATELLITE
  - VISUAL
  - IR
  - TEMPERATURE SOUNDINGS
- CONVENTIONAL
  - SURFACE
  - UPPER AIR
  - PILOT REPORTS

ANALYSIS CHARACTERISTICS

- 25 NM
- UPDATED EVERY 3 HOURS
- TOTALLY AUTOMATED

CLOUD FORECAST MODEL

- PROCESSED EVERY THREE HOURS
- FORECASTS TO 48 HOURS
  - CLOUD COVER
  - PRECIPITATION

SUMMARY OF RECORDED DATA MODE CAPABILITIES

-- AFGWC PROCESSING AND APPLICATION

- COMPLEX HARDWARE/SOFTWARE MIX

- 95% DATA USAGE RELIABILITY

DMSP DIRECT READOUT

- DOD REQUIREMENT SATISFACTION
  - -- WORLDWIDE
  - -- RESPONSIVE
  - -- SECURE
  - -- HIGH RESOLUTION
- COMPLETE SYSTEM
  - -- SATELLITE TO CUSTOMER
    - --- VISUAL AND IR SENSORS
    - --- TACTICAL TERMINALS

TACTICAL USES

- COMBAT TARGET ACQUISITION
  - VIETNAM
- CRISIS DATA DENIAL
  - YOM KIPPUR WAR
- NATO COMMITMENTS
  - EUROPE
- COMBAT DEPLOYMENT
  - READINESS COMMAND
  - AIRCRAFT DEPLOYMENTS
- DOD RESOURCE PROTECTION
  - JOINT TYPHOON WARNING CENTER

TARGET ACQUISTION

"THIS (DMSP) WEATHER PICTURE IS PROBABLY THE GREATEST INNOVATION OF THE WAR."
GEN WILLIAM MOMYER (1967)

"WITHOUT THEM (DMSP PHOTOS) .... MANY MISSIONS WOULD NOT HAVE BEEN LAUNCHED."
GEN WILLIAM MOMYER (1978)

COMBAT SUPPORT - VIETNAM

- STRIKE MISSIONS
  - GO/NO GO LAUNCH
  - IN-THEATER TACTICAL TERMINALS
- SON TAY RAID
  - TIMING
  - DATA DENIAL
  - SECRECY

CRISIS DATA DENIAL

- YOM KIPPUR WAR
  - NATIONS STOP WEATHER EXCHANGE
  - DMSP
    - -- ONLY DATA SOURCE
    - -- AIDED CRITICAL RESUPPLY
  - PROSPECTS IN EUROPE
  - NICARAGUAN CONTINGENCY

COMBAT DEPLOYMENT

- REDCOM
  - WORLDWIDE MISSION
  - LIMITED WEATHER DATA
    - -- DATA SPARSE REGIONS
    - -- DATA DENIAL
- TAC DEPLOYMENTS
  - NATO COMMITMENTS
  - LAUNCH/REFUELING DECISIONS

DOD RESOURCE PROTECTION

- JOINT TYPHOON WARNING CENTER (JTWC)
  - STORM WARNING
  - RESOURCE PROTECTION
  - SATELLITE STORM POSITIONING

    WESTPAC - 50%

    INDIAN OCEAN - 95%
  - MILITARY REQUIREMENT/CIVIL AVAILABILITY

FUTURE DMSP - AWS SUPPORT

LIMITED DOD RESOURCES - CONTINUED WORLD TENSION - NEW WEAPONS DRIVE

- INCREASED DMSP RESPONSIVENESS

- FURTHER EXPLOITATION/EXPANSION OF DMSP

DMSP IMPROVEMENTS

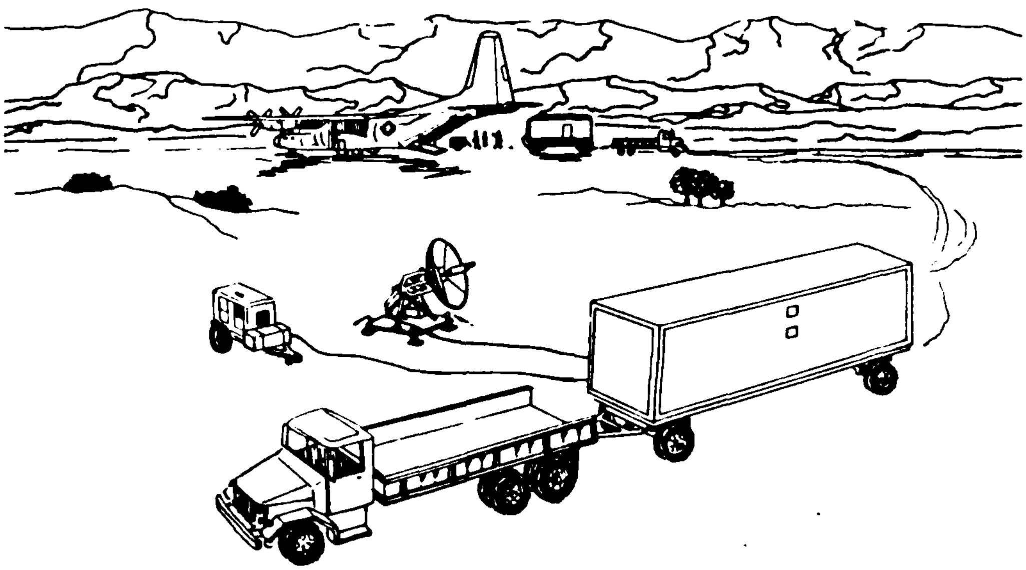
SPACE ENVIRONMENT MISSION

MICROWAVE IMAGER

AUTOMATED IMAGERY PROCESSING IMPROVEMENT

IMPROVED CLOUD ANALYSIS/FORECAST

MARK IV TACTICAL DEPLOYMENT



TACTICAL VAN IMPROVEMENTS

MULTIPLE SENSOR DATA

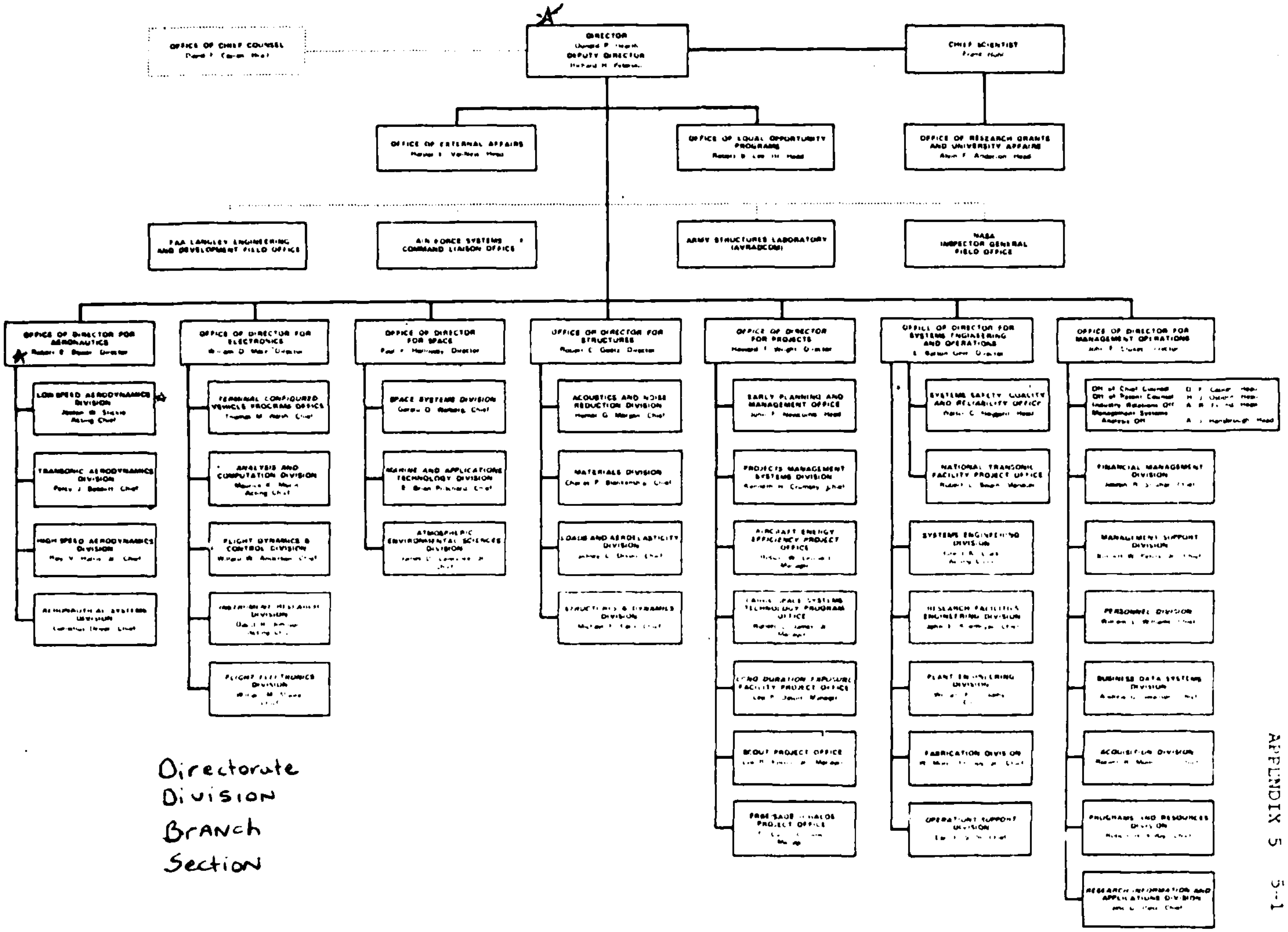
- MICROWAVE IMAGER
- ATMOSPHERIC SOUNDERS

DATA PROCESSING CAPABILITY

SUMMARY

- DMSP
  - FINE TUNED TOTAL SYSTEM
  - RESPONSIVE TO MILITARY REQUIREMENTS

LANGLEY RESEARCH CENTER

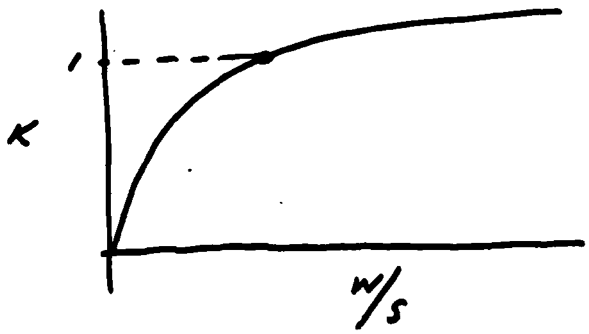


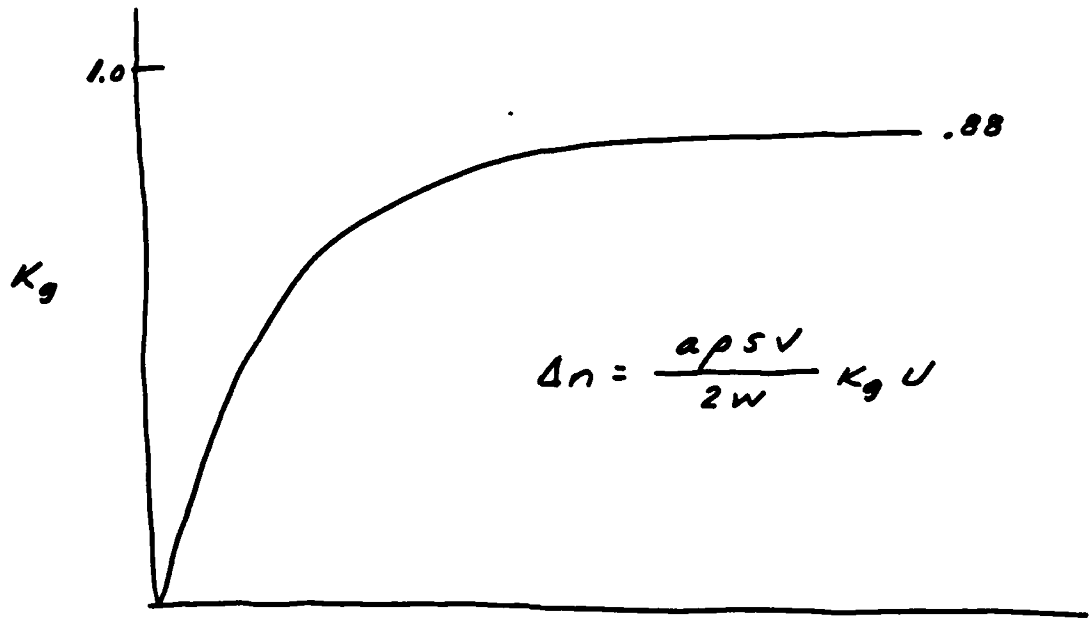
Directorate
Division
Branch
Section

$$L = \Delta n W = \frac{a}{2} \rho S V^2 \frac{U}{V}$$

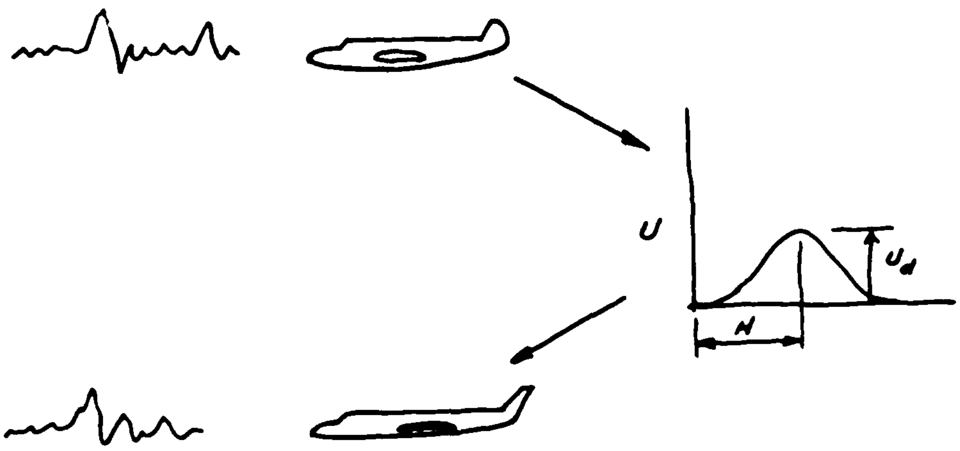
$$\Delta n = \frac{a \rho S V}{2W} U$$

$$\Delta n = \frac{a \rho S V}{2W} K U$$





$$\mu = \frac{2W}{a \rho c g S}$$


U
U_d
N

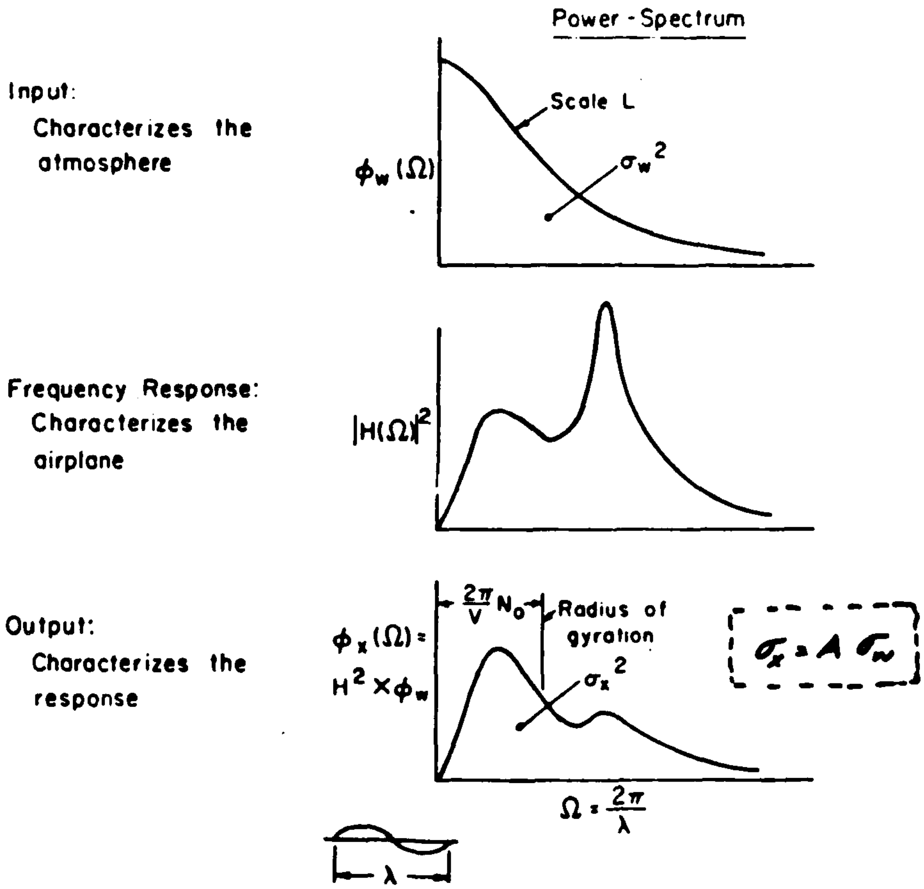


Fig. 1.- Input-Output Relation for Gust Response

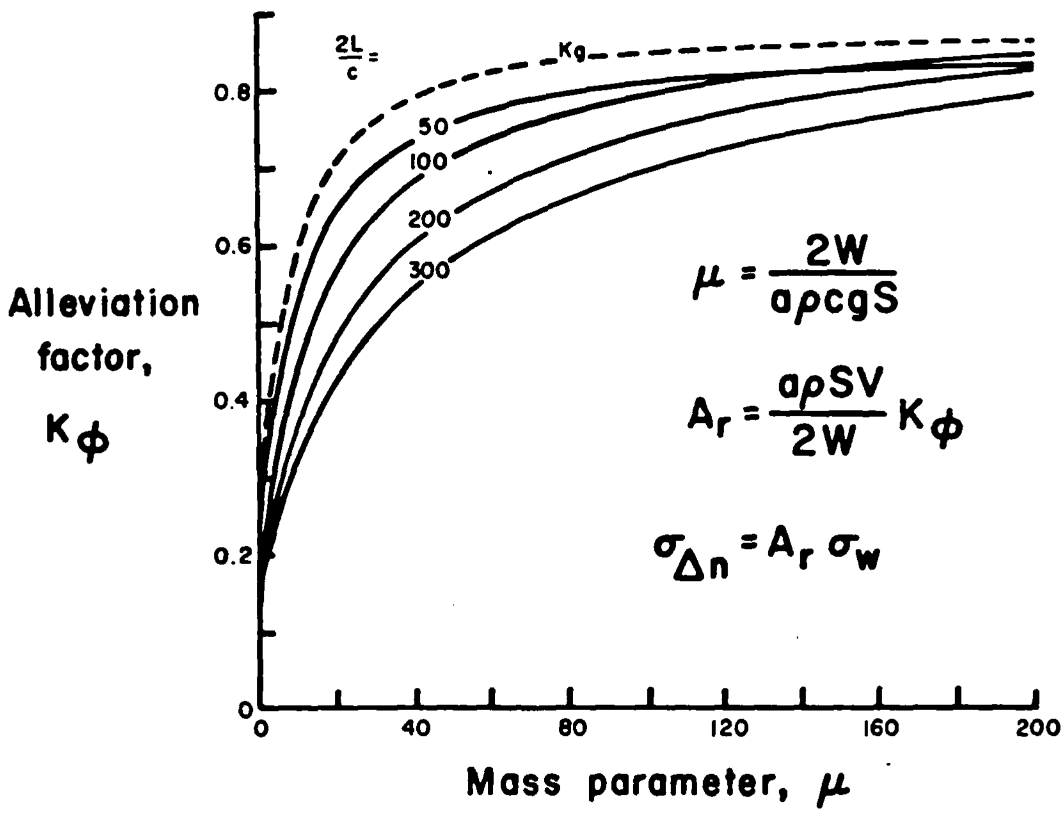
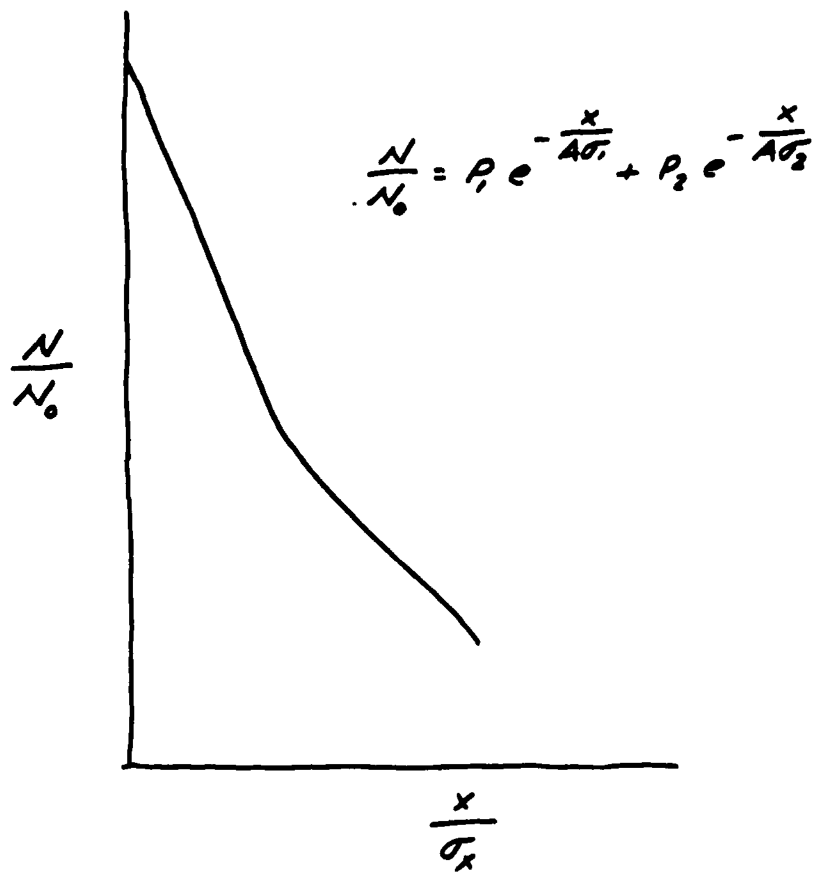


Fig. 3.- Spectral Results for Rigid Airplane


$\frac{N}{N_0} = P_1 e^{-\frac{x}{A\sigma_1}} + P_2 e^{-\frac{x}{A\sigma_2}}$
$\frac{N}{N_0}$
$\frac{x}{\sigma_x}$

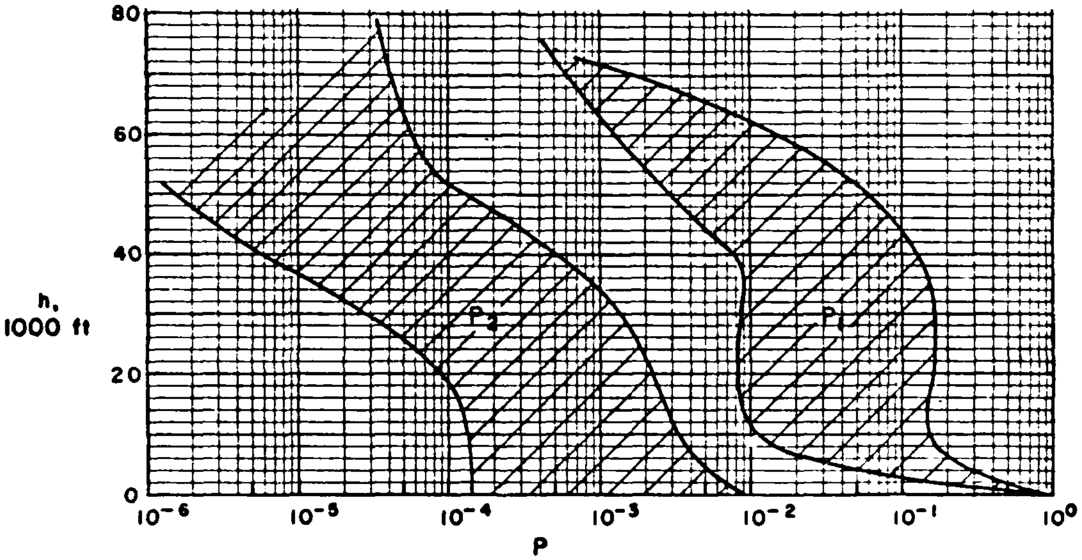


Figure 1. Range of P_1 and P_2 values indicated by various studies

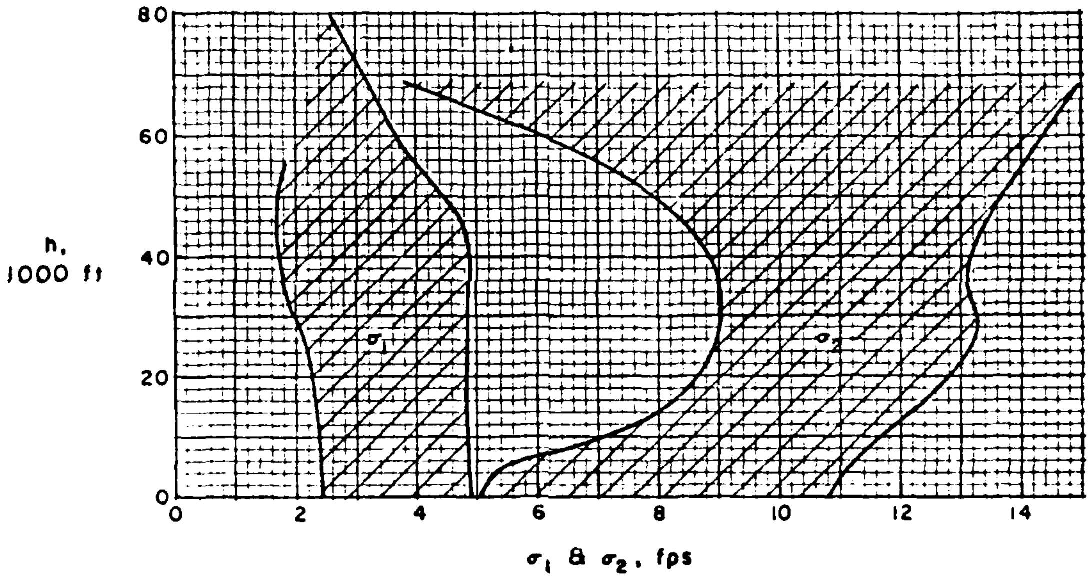


Figure 2. Range in σ_1 and σ_2 values indicated by various studies

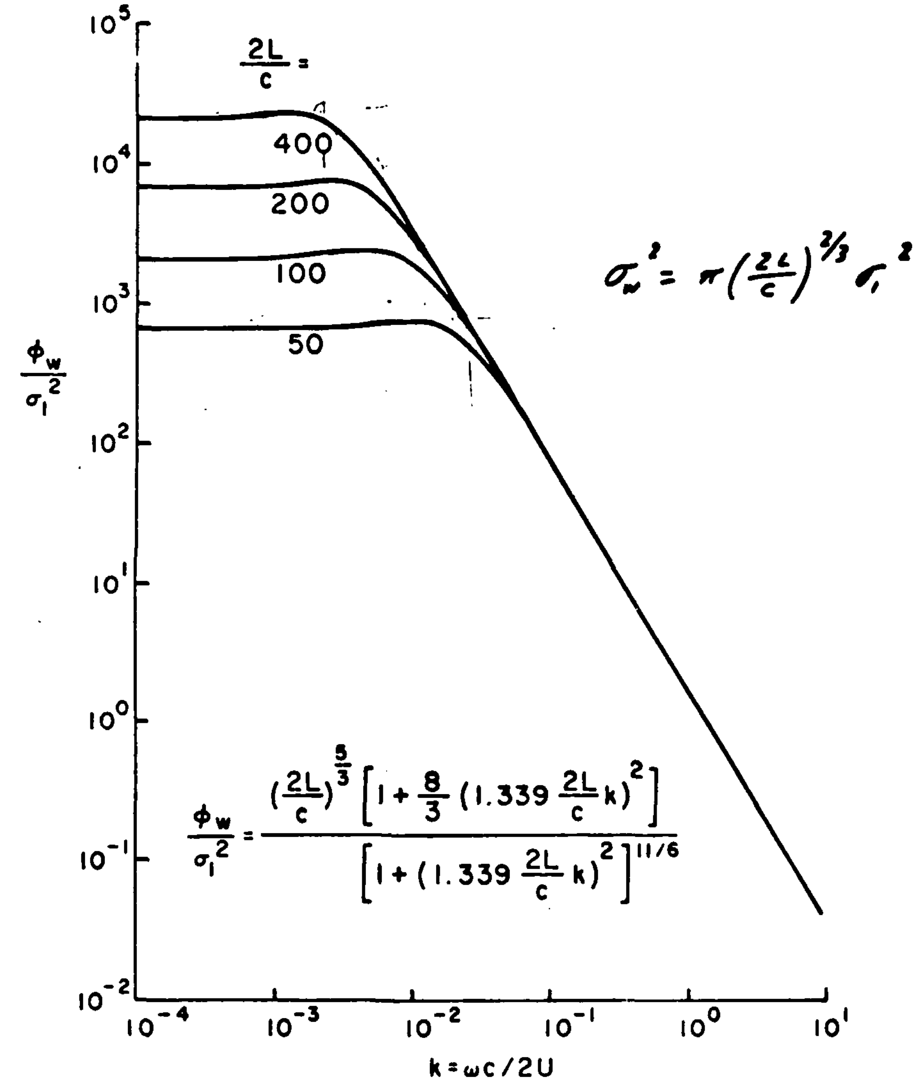


Figure 4.- Gust Input Spectrum Independent of $\frac{2L}{c}$ at High Frequencies

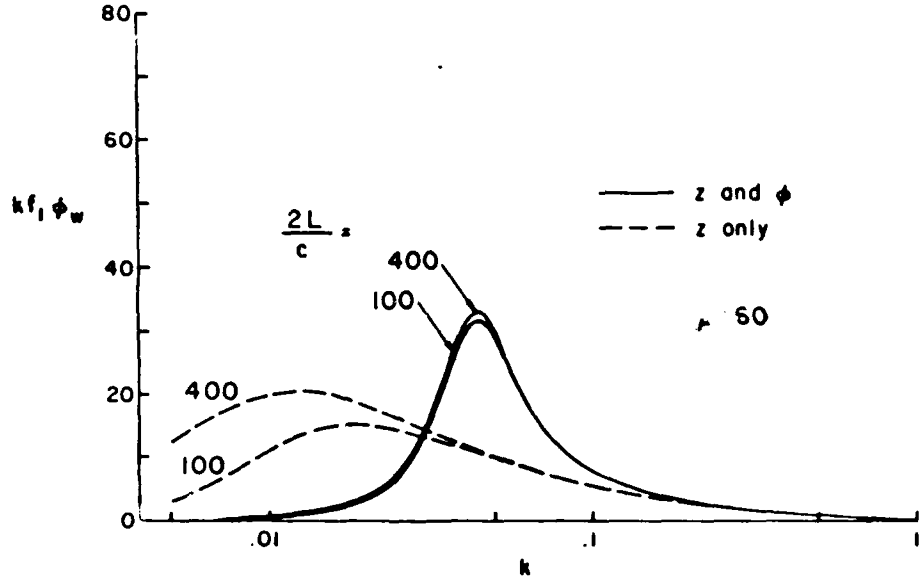
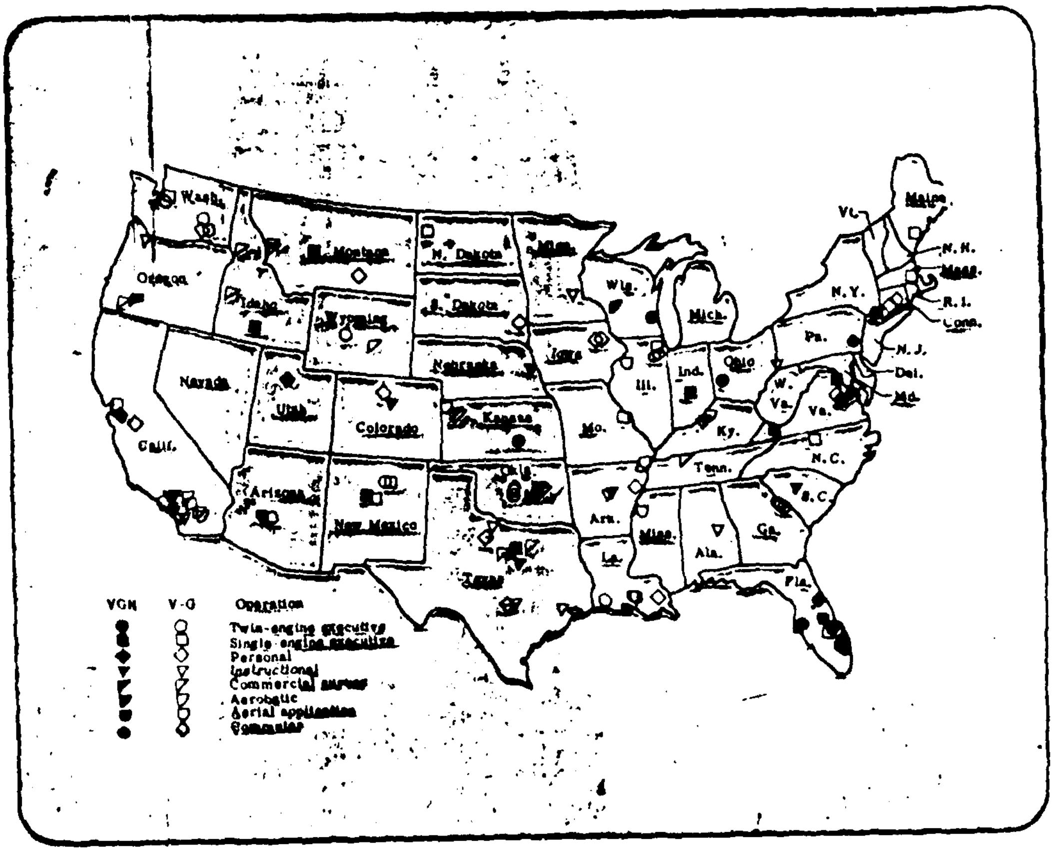
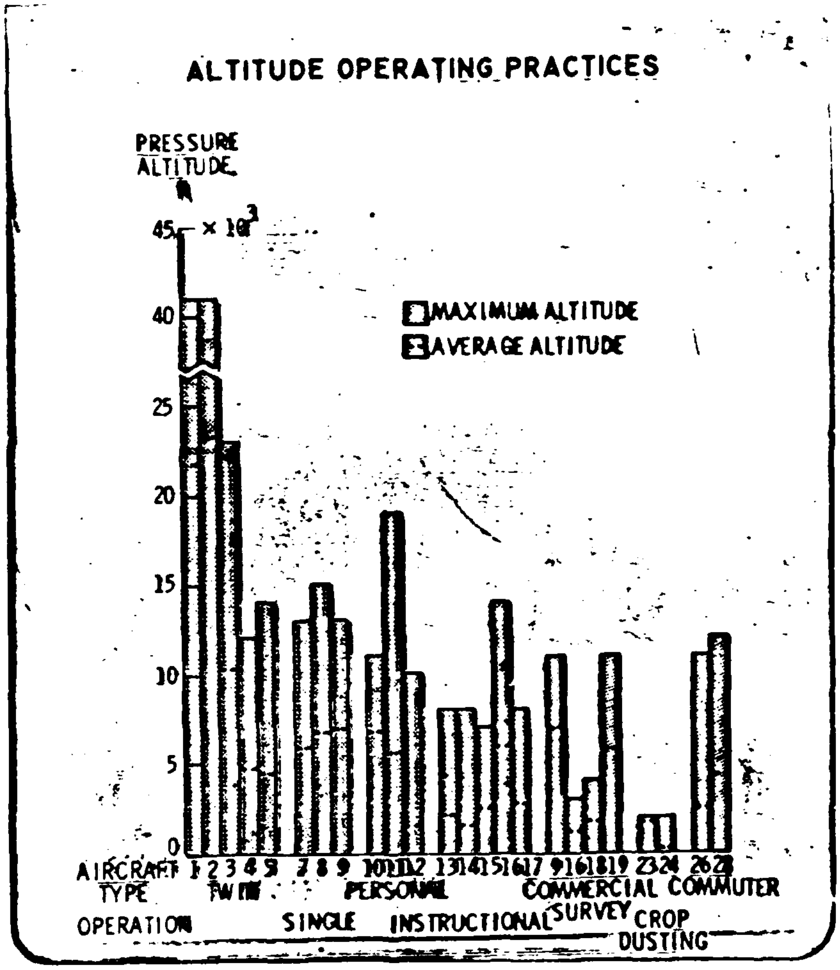


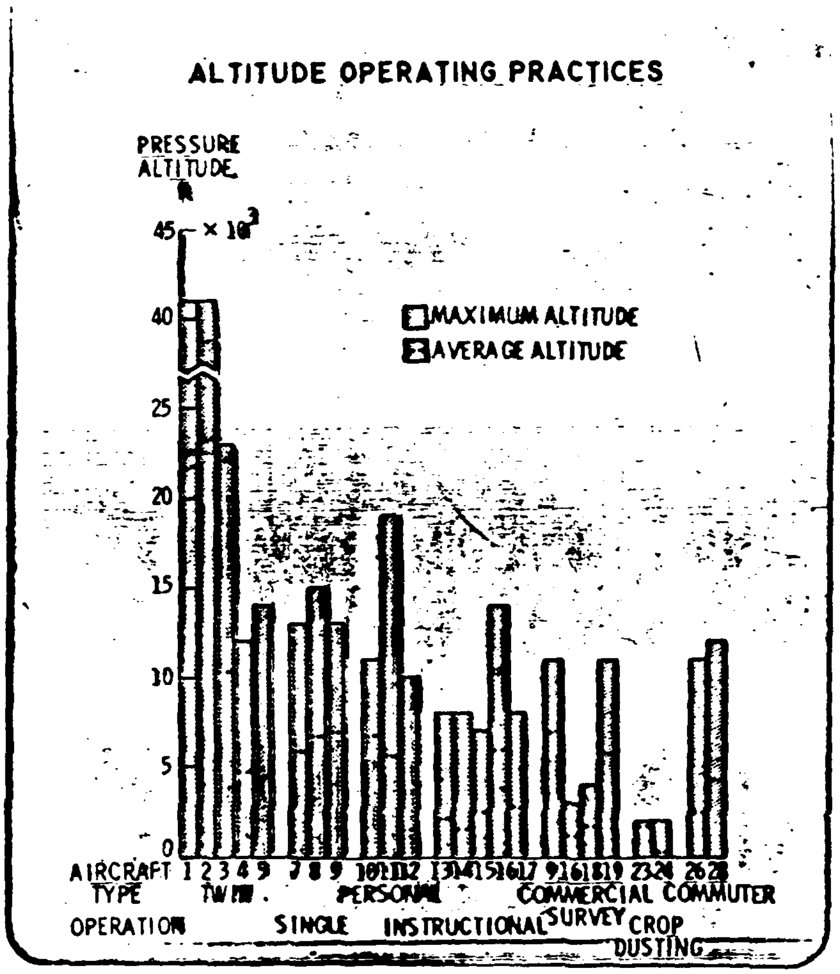
Figure 7.- Distribution of Response Power for One and Two Degrees of Freedom

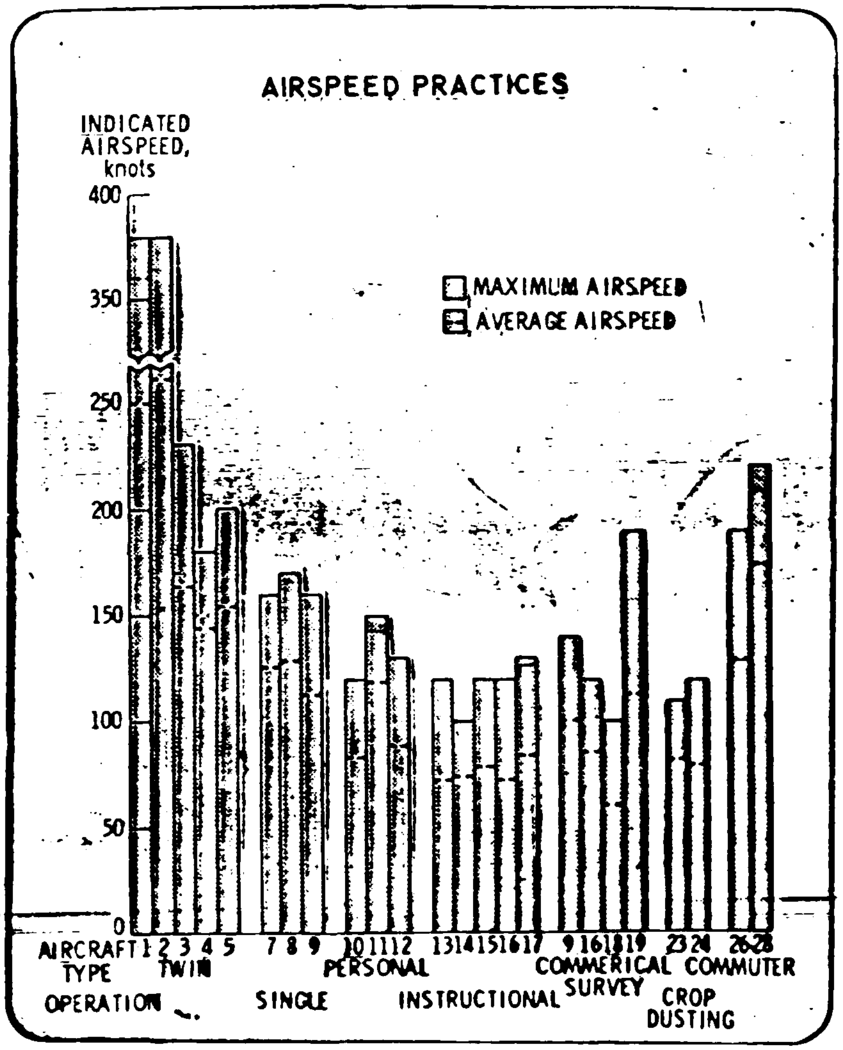
VG/VGH GENERAL AVIATION PROGRAM STATUS

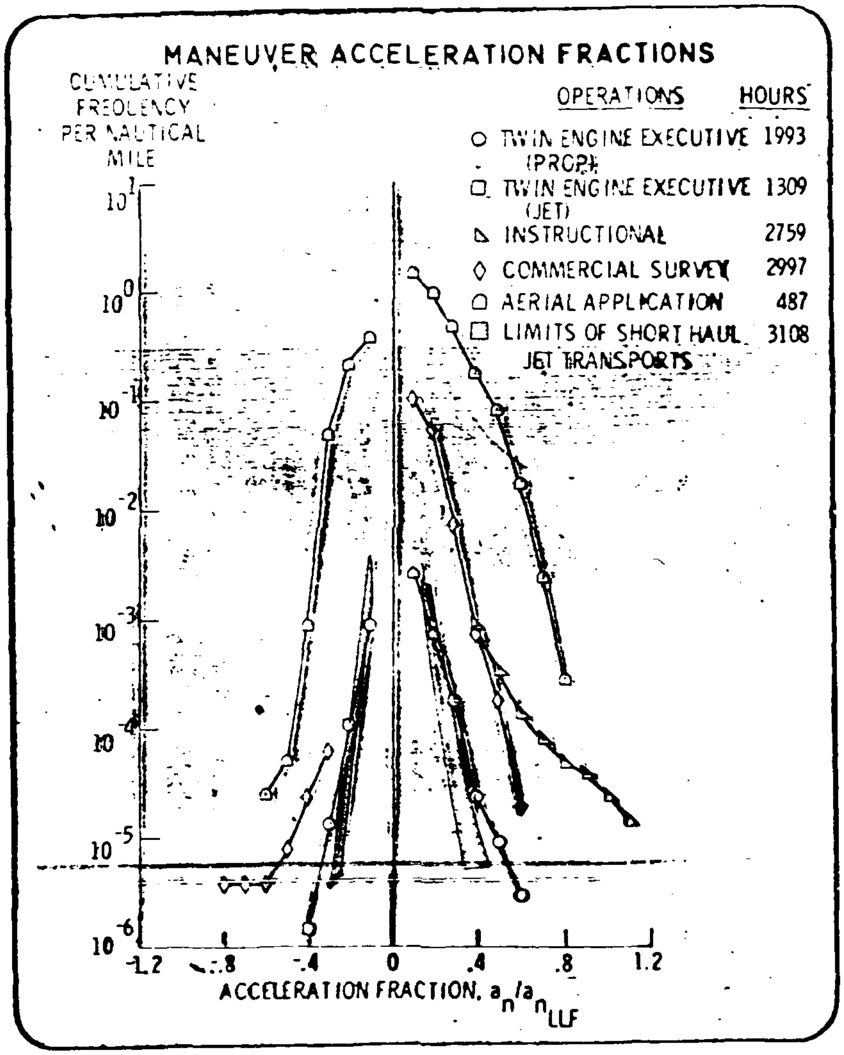
	COLLECTED				REPORTED			
	VGH DATA		VG DATA		VGH DATA		VG DATA	
OPERATIONS	AIRPLANES	HOURS	AIRPLANES	HOURS	AIRPLANES	HOURS	AIRPLANES	HOURS
TWIN-ENGINE EXECUTIVE	11	4,975	20	20,795	9	3,909	18	13,622
SINGLE-ENGINE EXECUTIVE	9	2,020	16	12,125	8	1,182	15	7,808
PERSONAL	10	1,558	23	11,504	6	712	16	5,283
INSTRUCTIONAL	8	4,031	22	18,413	6	2,759	17	9,499
COMMERCIAL SURVEY	8	3,154	15	38,979	4	2,997	14	23,585
AEROBATIC	1	12	5	721	1	12	5	406
AERIAL APPLICATION	4	1,040	9	4,638	2	487	7	1,637
COMMUTER	2	4,263	7	16,078	2	940	5	4,358
TOTAL	53	21,053	117	123,253	38	12,998	97	66,198

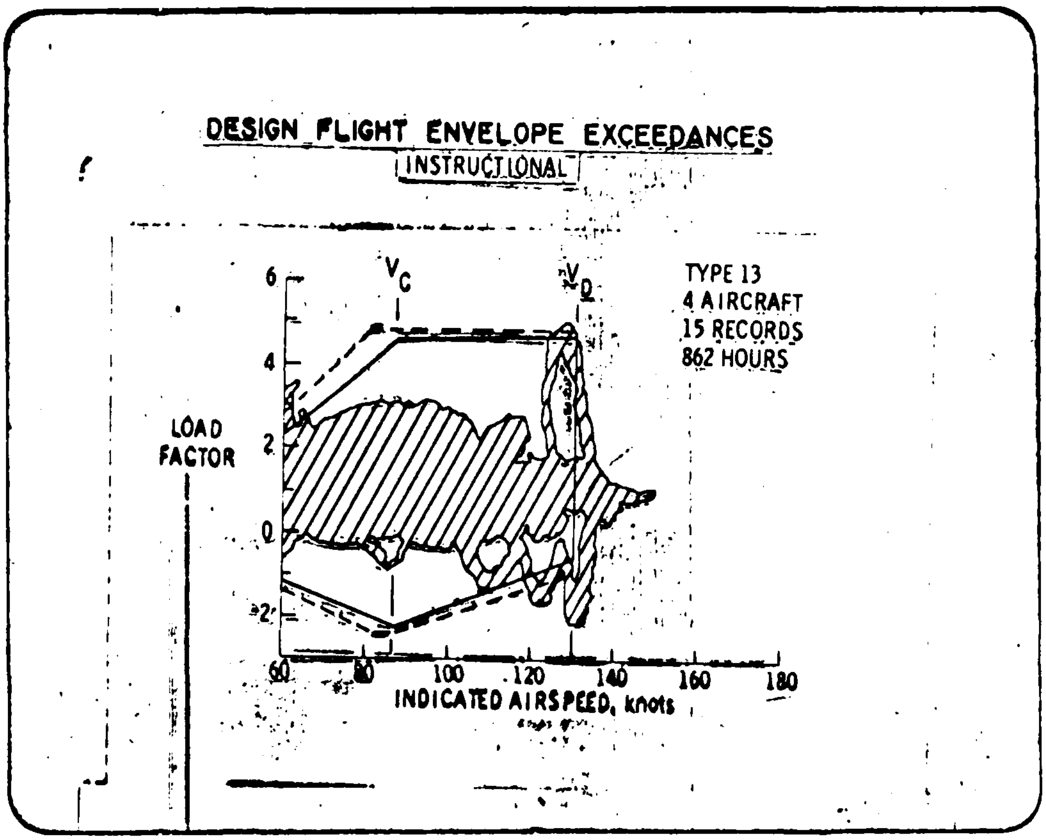

Wash.
Oregon
Idaho
Montana
N. Dakota
Minn.
S. Dakota
Wyoming
Nevada
Utah
Colorado
Nebraska
Kansas
Iowa
Wis.
Mich.
Ill.
Ind.
Ohio
Mo.
Ky.
Calif.
Arizona
New Mexico
Okla.
Texas
Ark.
La.
Miss.
Ala.
Tenn.
Ga.
Fla.
S.C.
N.C.
Va.
W. Va.
Pa.
N.Y.
Vt.
Maine
N.H.
Mass.
R.I.
Conn.
N.J.
Del.
Md.
VGN
V-G
Operation
Twin-engine executive
Single-engine executive
Personal
Instructional
Commercial survey
Aerobatic
Aerial application
Commuter


ALTITUDE OPERATING PRACTICES
PRESSURE ALTITUDE
× 10³
45
40
25
20
15
10
5
0
MAXIMUM ALTITUDE
AVERAGE ALTITUDE
AIRCRAFT TYPE
TWIN
SINGLE
OPERATION
PERSONAL
INSTRUCTIONAL
COMMERCIAL
SURVEY
CROP DUSTING
COMMUTER

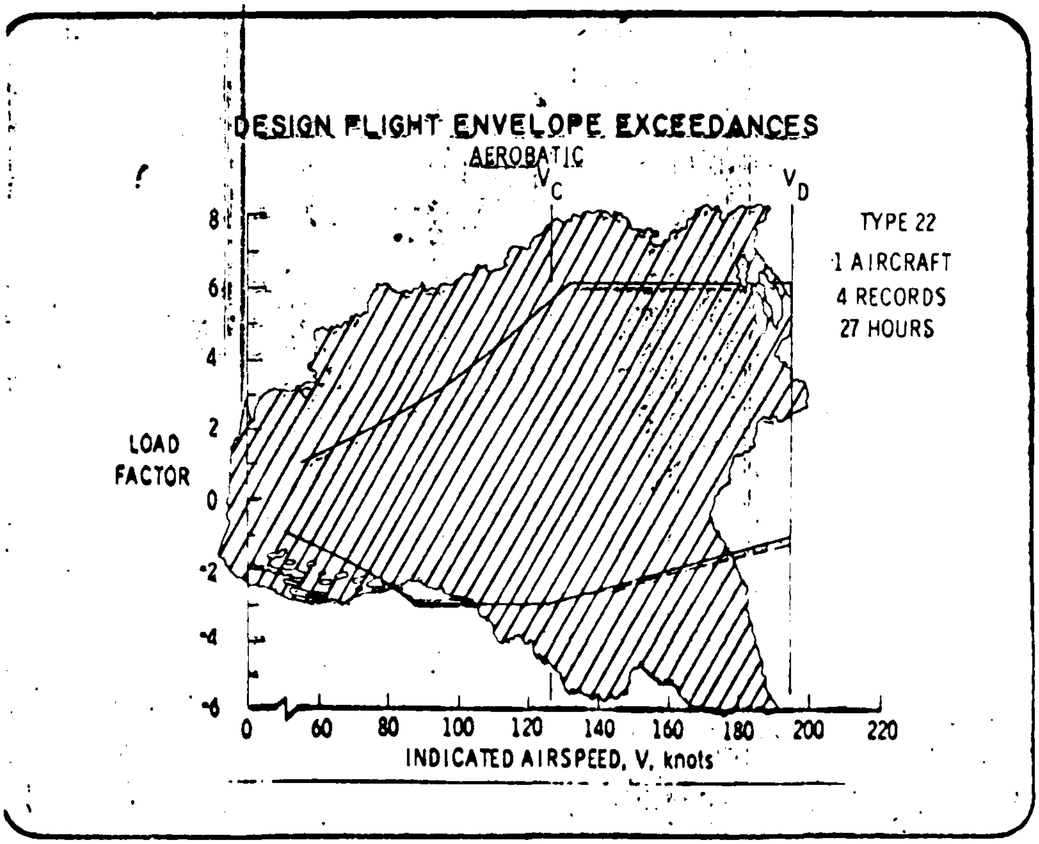

ALTITUDE OPERATING PRACTICES
PRESSURE ALTITUDE
ft
× 10³
45
40
25
20
15
10
5
0
MAXIMUM ALTITUDE
AVERAGE ALTITUDE
AIRCRAFT TYPE
OPERATION
TWIN
SINGLE
PERSONAL
INSTRUCTIONAL
COMMERCIAL
SURVEY
CROP DUSTING
COMMUTER


AIRSPEED PRACTICES
INDICATED AIRSPEED, knots
400
350
250
200
150
100
50
0
MAXIMUM AIRSPEED
AVERAGE AIRSPEED
AIRCRAFT TYPE
OPERATION
1 2 3 4 5
TWIN
7 8 9
SINGLE
10 11 12
PERSONAL
13 14 15 16 17
INSTRUCTIONAL
9 16 18 19
COMMERICAL SURVEY
23 24
CROP DUSTING
26 28
COMMUTER

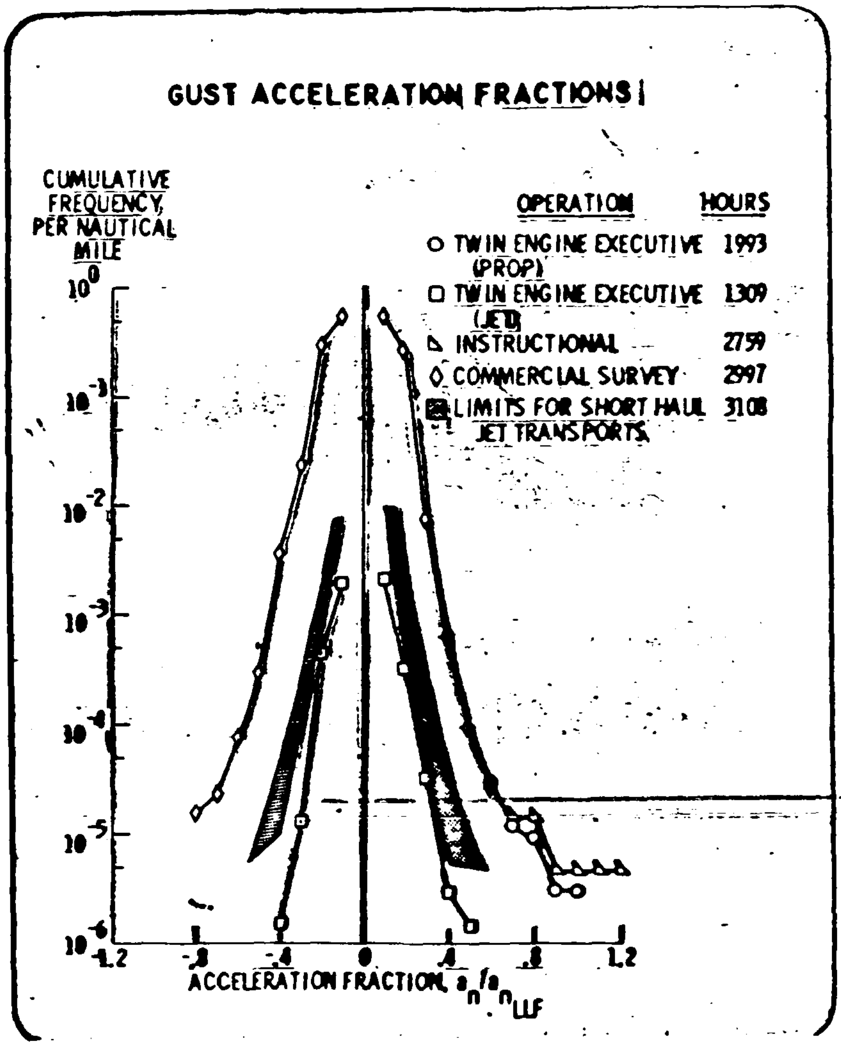

MANEUVER ACCELERATION FRACTIONS
CUMULATIVE FREQUENCY PER NAUTICAL MILE
OPERATIONS HOURS
TWIN ENGINE EXECUTIVE (PROP) 1993
TWIN ENGINE EXECUTIVE (JET) 1309
INSTRUCTIONAL 2759
COMMERCIAL SURVEY 2997
AERIAL APPLICATION 487
LIMITS OF SHORT HAUL JET TRANSPORTS 3108
ACCELERATION FRACTION, $a_n/a_{n_{LLF}}$

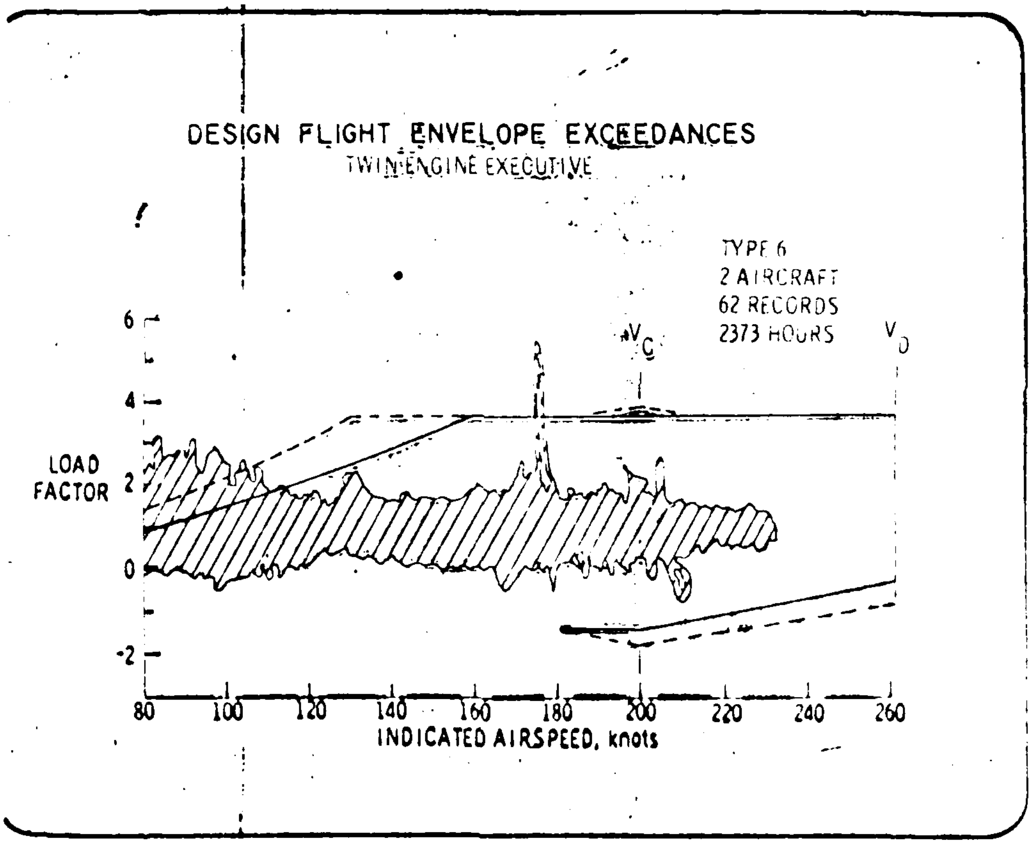

DESIGN FLIGHT ENVELOPE EXCEEDANCES
INSTRUCTIONAL
TYPE 13
4 AIRCRAFT
15 RECORDS
862 HOURS
LOAD FACTOR
INDICATED AIRSPEED, knots
V_C
V_D
6
4
2
0
-2
60
80
100
120
140
160
180

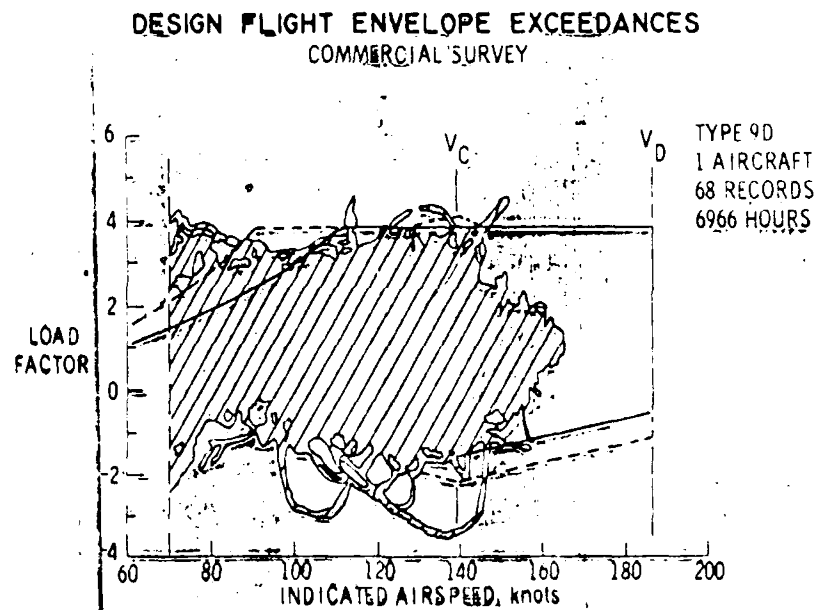
62



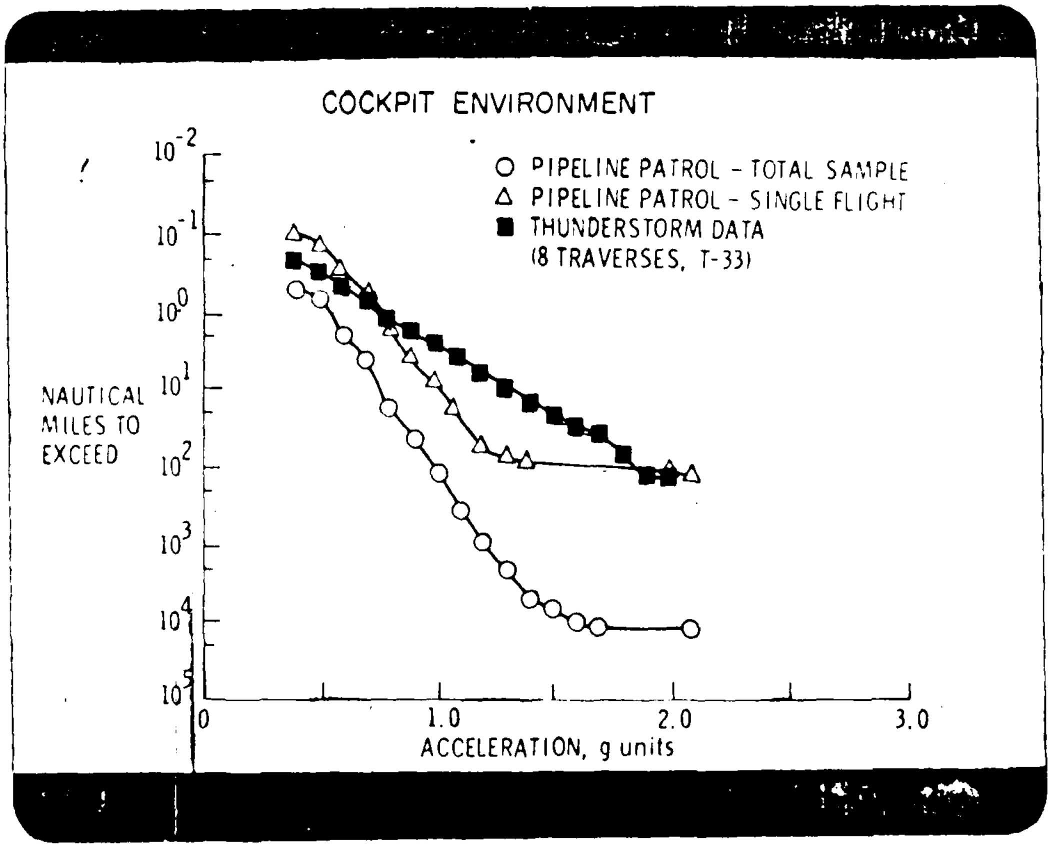
DESIGN FLIGHT ENVELOPE EXCEEDANCES
AEROBATIC
V_C
V_D
TYPE 22
1 AIRCRAFT
4 RECORDS
27 HOURS
LOAD FACTOR
8
6
4
2
0
-2
-4
-6
0
60
80
100
120
140
160
180
200
220
INDICATED AIRSPEED, V, knots

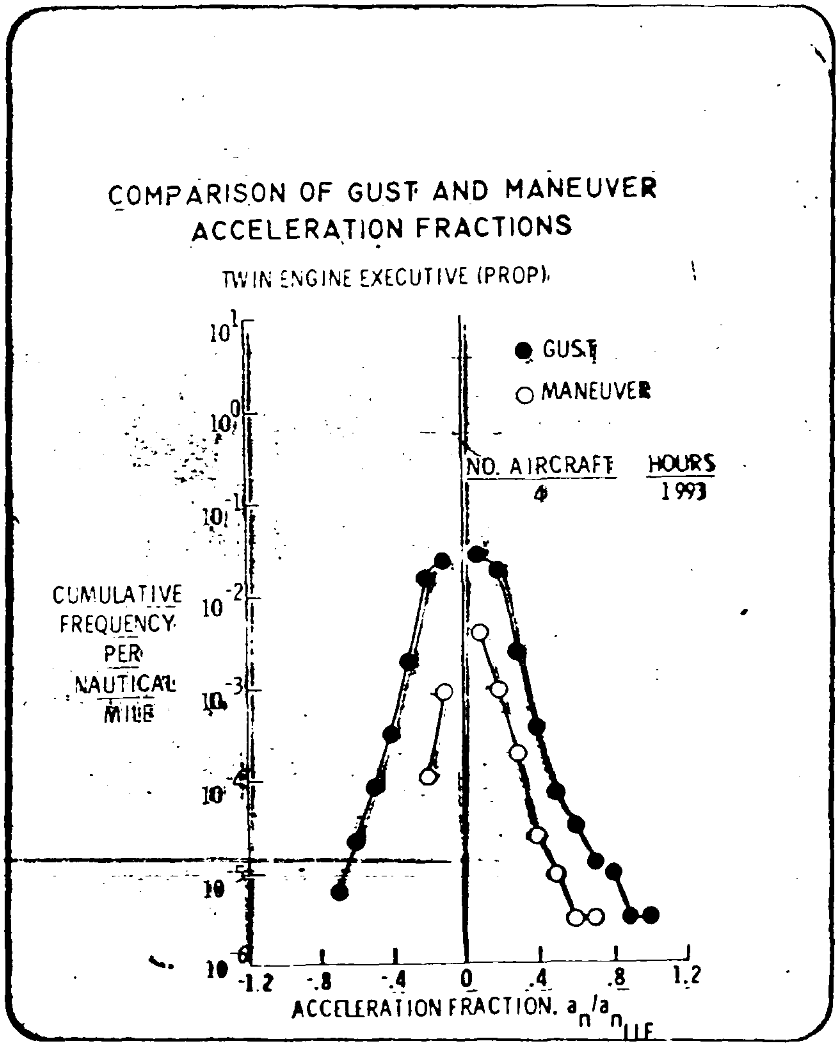

GUST ACCELERATION FRACTIONS
CUMULATIVE FREQUENCY, PER NAUTICAL MILE
OPERATION HOURS
O TWIN ENGINE EXECUTIVE (PROP) 1993
□ TWIN ENGINE EXECUTIVE (JET) 1309
△ INSTRUCTIONAL 2759
◇ COMMERCIAL SURVEY 2997
LIMITS FOR SHORT HAUL JET TRANSPORTS 3108
ACCELERATION FRACTION, $a_n/a_{n_{LLF}}$


DESIGN FLIGHT ENVELOPE EXCEEDANCES
TWIN-ENGINE EXECUTIVE
TYPE 6
2 AIRCRAFT
62 RECORDS
2373 HOURS
V_C
V_D
LOAD FACTOR
6
4
2
0
-2
80
100
120
140
160
180
200
220
240
260
INDICATED AIRSPEED, knots


DESIGN FLIGHT ENVELOPE EXCEEDANCES
COMMERCIAL SURVEY
TYPE 9D
1 AIRCRAFT
68 RECORDS
6966 HOURS
V_C
V_D
LOAD FACTOR
6
4
2
0
-2
-4
60
80
100
120
140
160
180
200
INDICATED AIRSPEED, knots

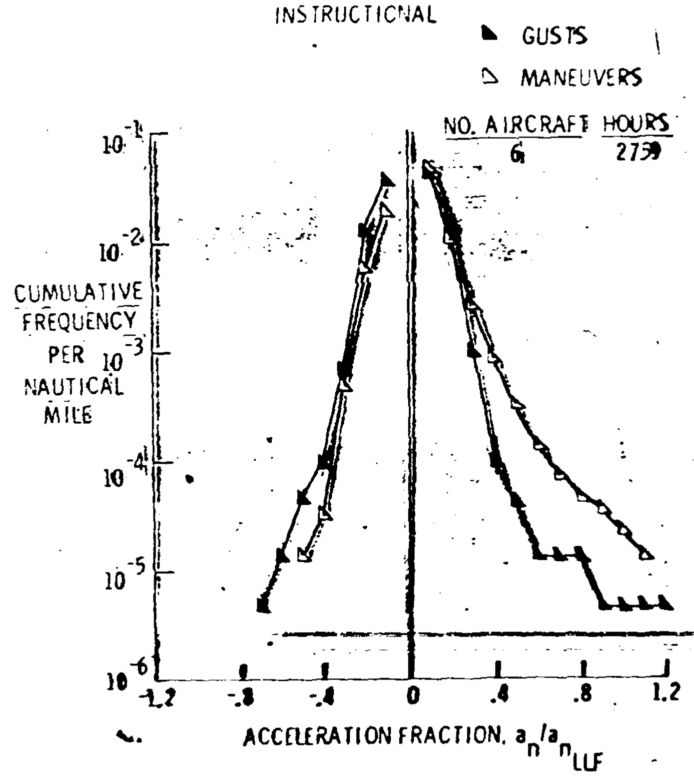
66

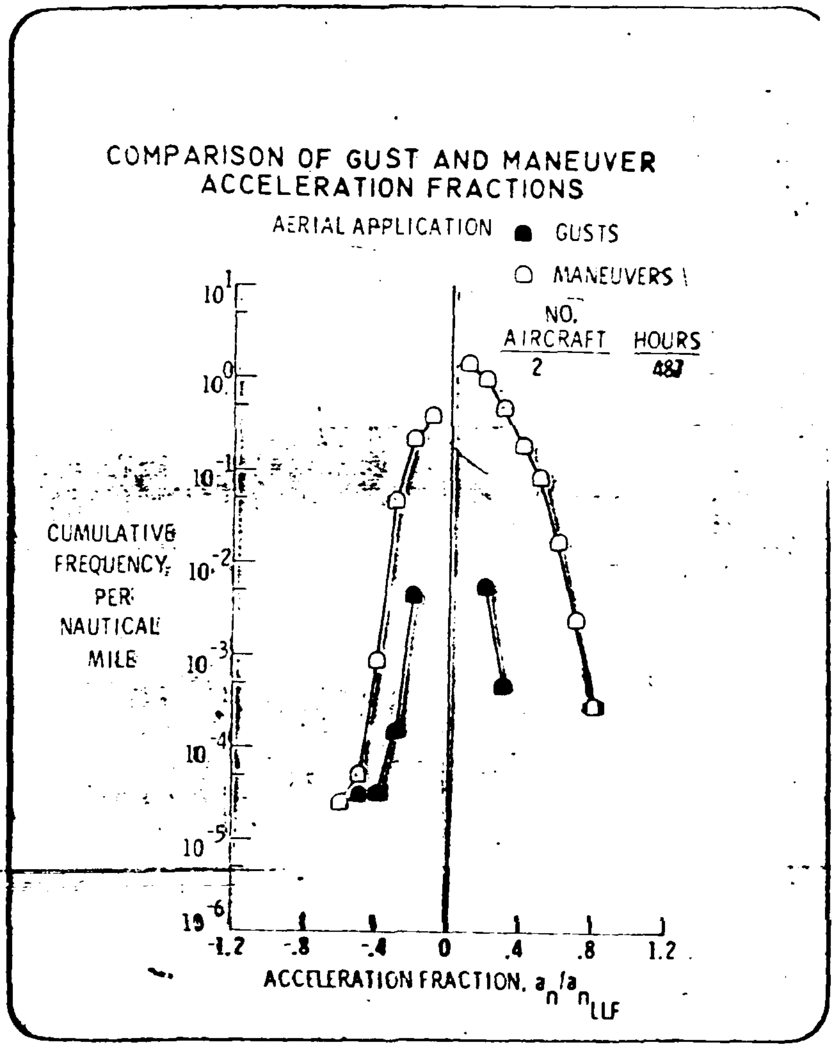

COCKPIT ENVIRONMENT
PIPELINE PATROL - TOTAL SAMPLE
PIPELINE PATROL - SINGLE FLIGHT
THUNDERSTORM DATA
(8 TRAVERSES, T-33)
NAUTICAL MILES TO EXCEED
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
0
1.0
2.0
3.0
ACCELERATION, g units


COMPARISON OF GUST AND MANEUVER
ACCELERATION FRACTIONS
TWIN ENGINE EXECUTIVE (PROP)
GUST
MANEUVER
NO. AIRCRAFT
4
HOURS
1993
CUMULATIVE
FREQUENCY
PER
NAUTICAL
MILE
ACCELERATION FRACTION, $a_n/a_{n_{LLF}}$

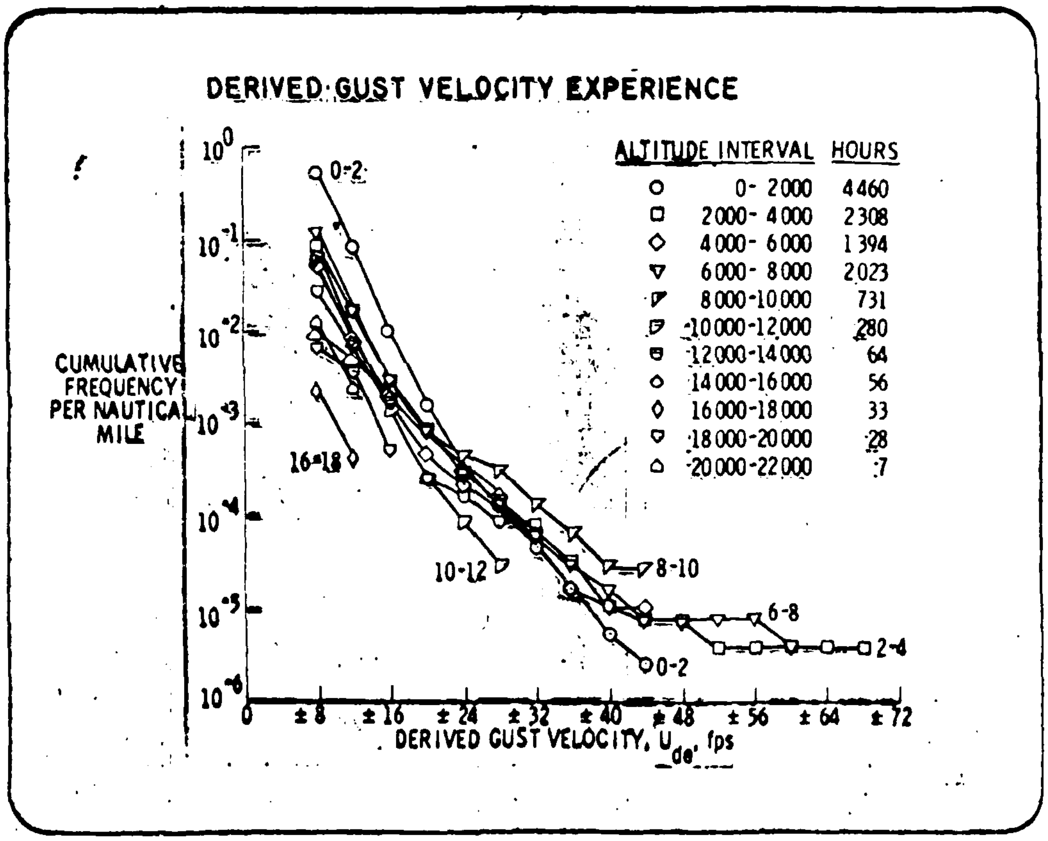
COMPARISON OF GUST AND MANEUVER ACCELERATION FRACTIONS

INSTRUCTIONAL





COMPARISON OF GUST AND MANEUVER ACCELERATION FRACTIONS
AERIAL APPLICATION
GUSTS
MANEUVERS
NO. AIRCRAFT
2
HOURS
CUMULATIVE FREQUENCY, PER NAUTICAL MILE
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
-1.2
-.8
-.4
0
.4
.8
1.2
ACCELERATION FRACTION, a_n/a_n_LLF


DERIVED GUST VELOCITY EXPERIENCE
CUMULATIVE FREQUENCY PER NAUTICAL MILE
DERIVED GUST VELOCITY, U_{de}, fps
ALTITUDE INTERVAL HOURS
0- 2000 4460
2000- 4000 2308
4000- 6000 1394
6000- 8000 2023
8000-10000 731
10000-12000 280
12000-14000 64
14000-16000 56
16000-18000 33
18000-20000 28
20000-22000 7
0-2
16-18
10-12
8-10
6-8
2-4

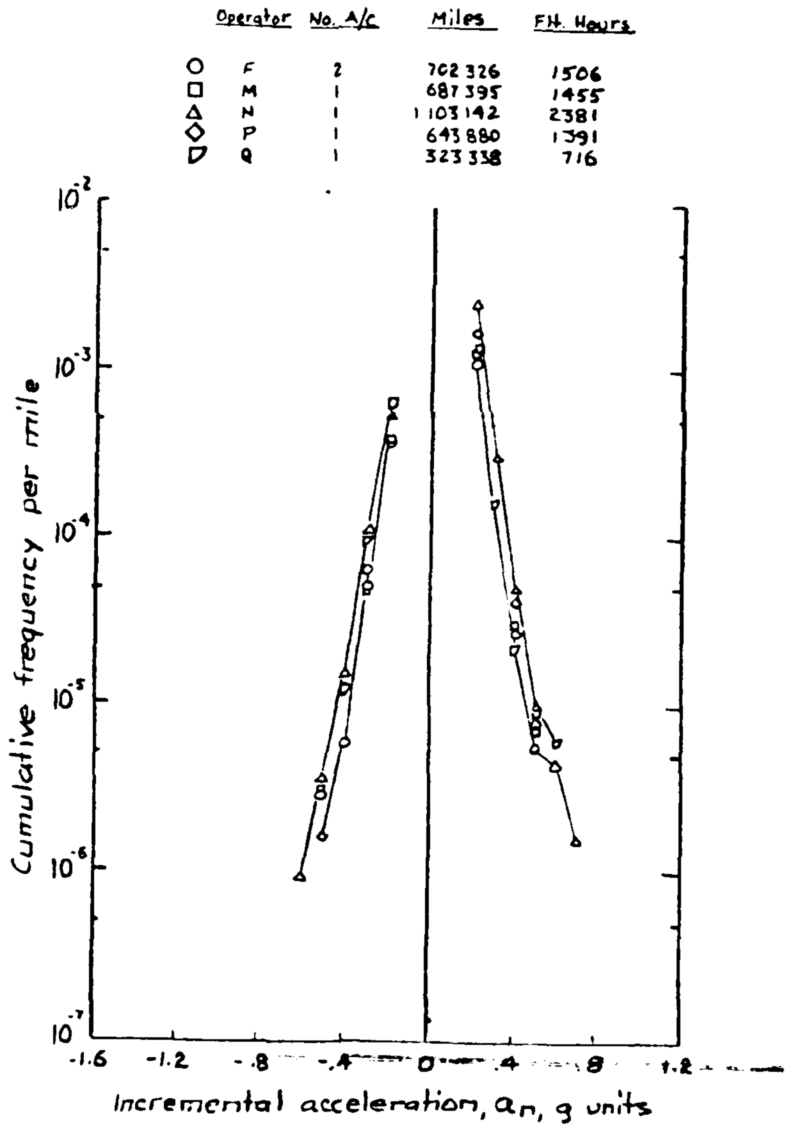
PREDICTIONS OF LANDINGS REQUIRED TO REACH OR EXCEED THE MINIMUM DESIGN LOAD FACTOR, 2.67

OPERATIONAL CATEGORY	NUMBER OF LANDINGS
AERIAL APPLICATION	860
INSTRUCTIONAL	3 393
SINGLE ENGINE EXECUTIVE	19 295
PERSONAL	19 554
COMMERCIAL SURVEY	81 321
TWIN ENGINE EXECUTIVE	269 297
COMMUTER	1 507 121

CONCLUSIONS

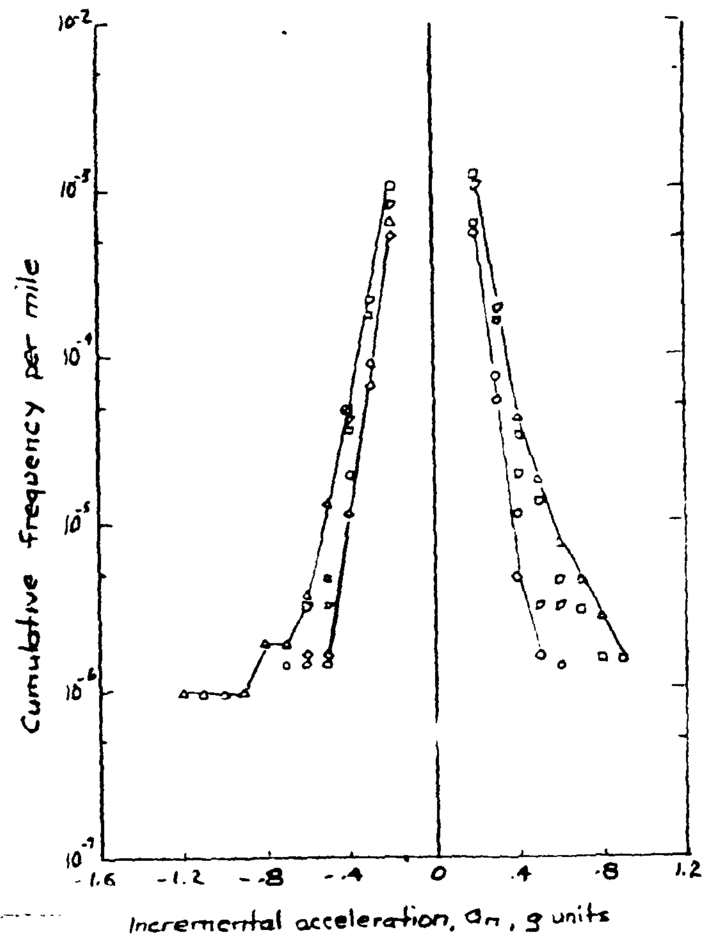
1. COMPETITIVE AEROBATIC AND INSTRUCTIONAL AIRPLANES REACH OR EXCEED THE DESIGN DIVING SPEED MORE FREQUENTLY THAN AIRPLANES IN OTHER TYPES OF OPERATIONS.
2. AVERAGE FLIGHT ALTITUDES FOR PISTON-POWERED AIRPLANES ARE BELOW 7,000 FT AND MAXIMUM ALTITUDES DO NOT EXCEED 15,000 FT.
3. THE MOST SEVERE OVERALL IN-FLIGHT LOADS ARE RECORDED BY AIRPLANES FLOWN IN COMPETITIVE AEROBATICS, AND IN PIPELINE PATROL OPERATIONS OVER MOUNTAINOUS REGIONS.
4. THE FREQUENCY OF OCCURRENCE OF GIVEN GUST ACCELERATIONS VARIES BY AS MUCH AS THREE ORDERS OF MAGNITUDE BETWEEN AIRPLANES FLOWN IN DIFFERENT OPERATIONS.
5. THE MOST SEVERE DERIVED GUST VELOCITIES FROM THE STANDPOINT OF MAGNITUDE AND FREQUENCY OF OCCURRENCE WERE EXPERIENCED BELOW 10,000 FT.
6. THE MOST SEVERE MANEUVER LOADS WERE EXPERIENCED BY AIRPLANES FLOWN IN AERIAL APPLICATIONS, COMPETITIVE AEROBATICS, AND INSTRUCTIONAL OPERATIONS.
7. GENERAL AVIATION AIRPLANES ARE FLOWN CLOSER TO THE DESIGN FLIGHT ENVELOP THAN COMMERCIAL TRANSPORT AIRPLANES.

OPERATIONAL MANEUVER ACCELERATIONS EXPERIENCED BY WIDE-BODY JET TRANSPORTS



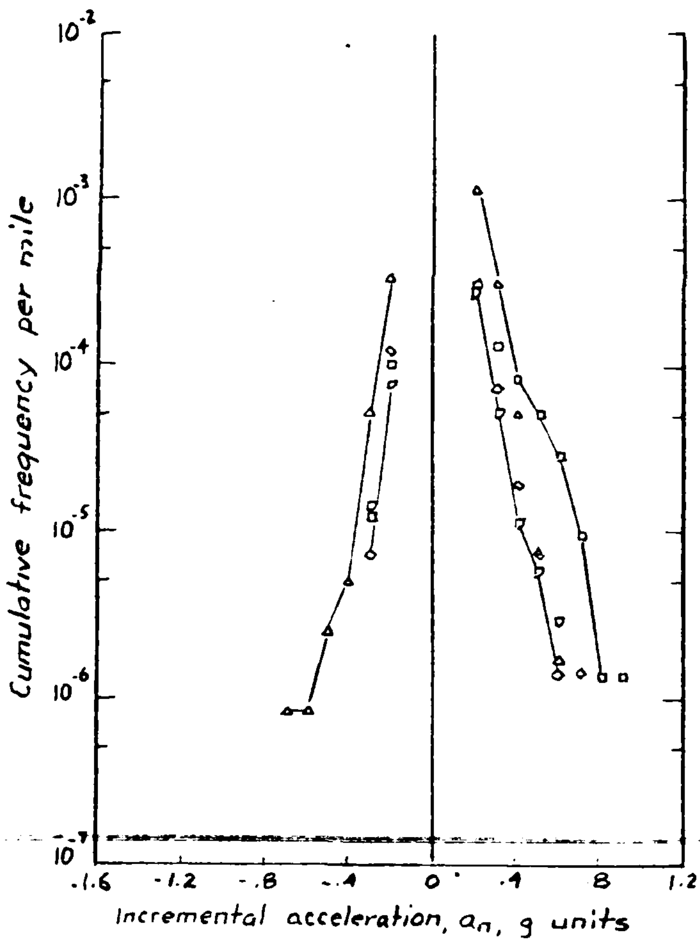
GUST ACCELERATIONS EXPERIENCED BY WIDE-BODY JET TRANSPORTS

	Operator	No A/C	Miles	Flt hours
○	F	2	702 326	1506
□	M	1	687 395	1455
△	N	1	1 103 142	2381
◇	P	1	643 880	1391
▷	Q	1	323 358	716



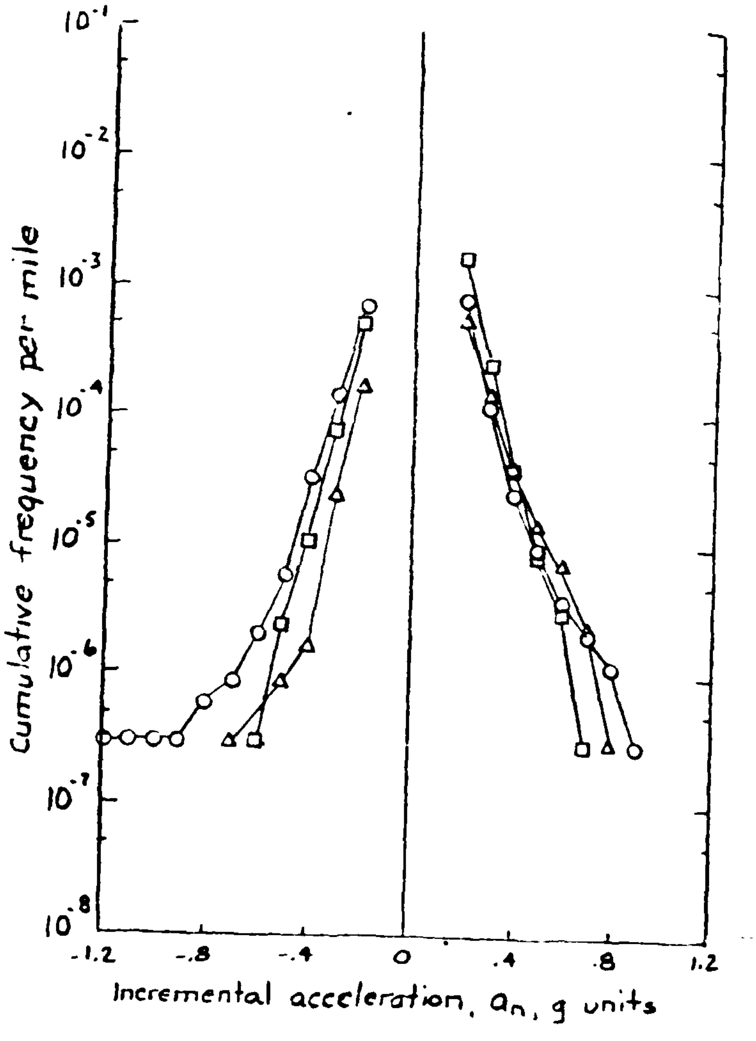
CHECK-FLIGHT MANEUVER ACCELERATIONS EXPERIENCED BY WIDE-BODY JET TRANSPORTS

	Operator	No. A/c	Miles	Flt. Hours
□	M	1	691 691	1474
△	N	1	1 115607	2450
◇	P	1	646707	1405
▽	Q	1	325970	727



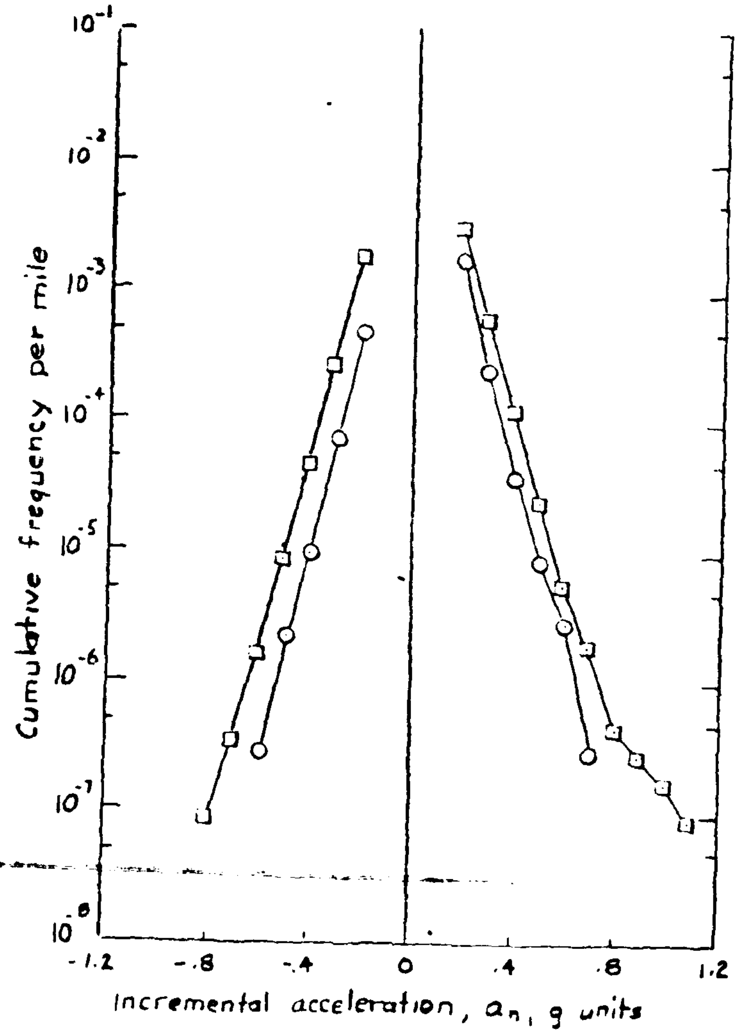
COMPARISON OF ACCELERATION SOURCES FOR WIDE-BODY JET TRANSPORTS

	Acceleration source	Miles	Hours
O	Gust	3 460 081	7450
□	Operational maneuver	3 460 081	7450
Δ	Check-flight maneuver	3 482 301	7562



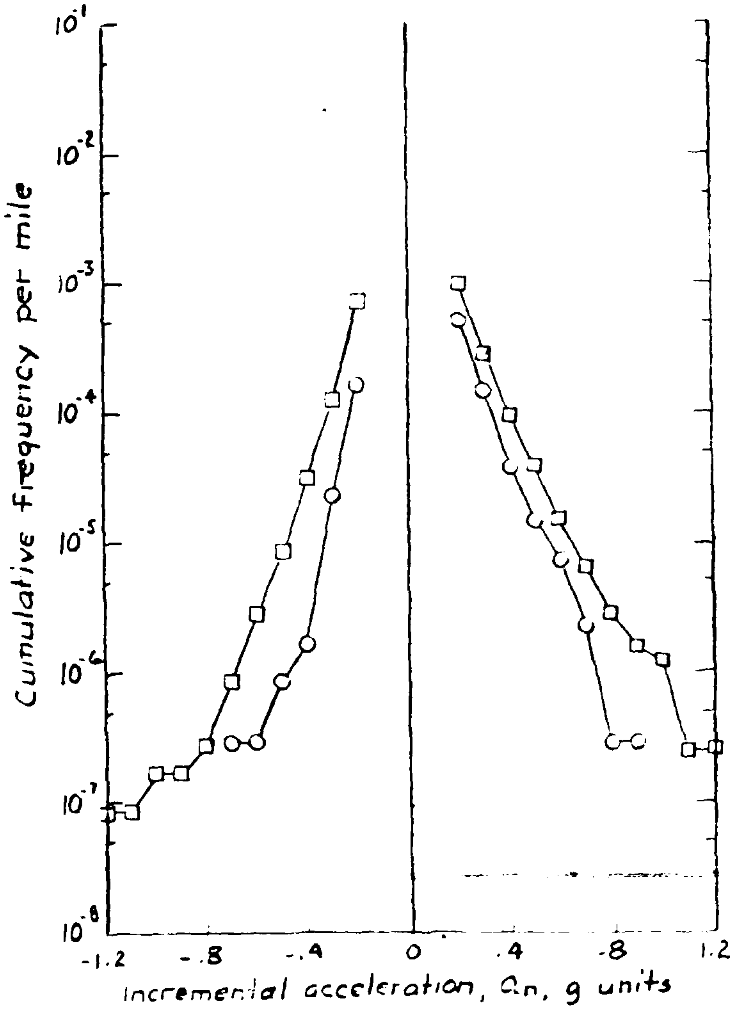
COMPARISON OF MANEUVER ACCELERATIONS FOR WIDE AND NARROW BODY JET TRANSPORTS

Aircraft type	No A/C	Miles	Flt hours
O Wide body	6	3 460 081	7 450
□ Narrow body	12	11 820 850	26 854



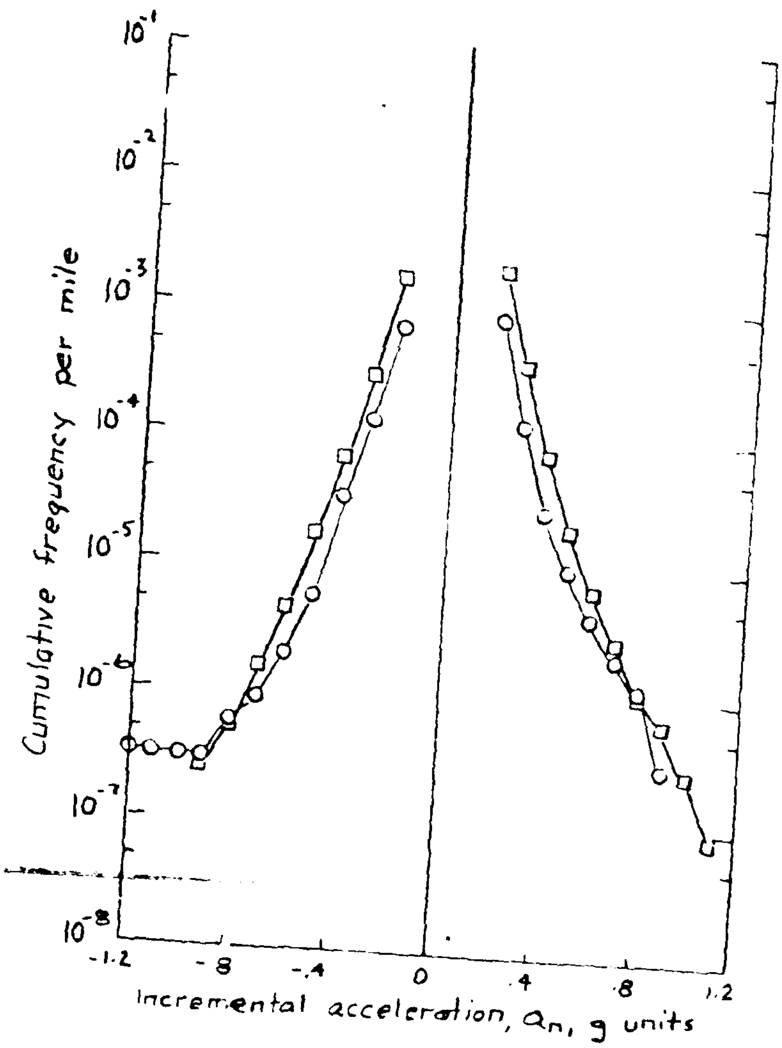
COMPARISON OF CHECK-FLIGHT MANEUVER ACCELERATIONS FOR WIDE AND NARROW-BODY JET TRANSPORTS

Aircraft type	No A/C	Miles	FH hours
Wide body	6	3 482 301	7562
Narrow body	12	12 092 676	27410

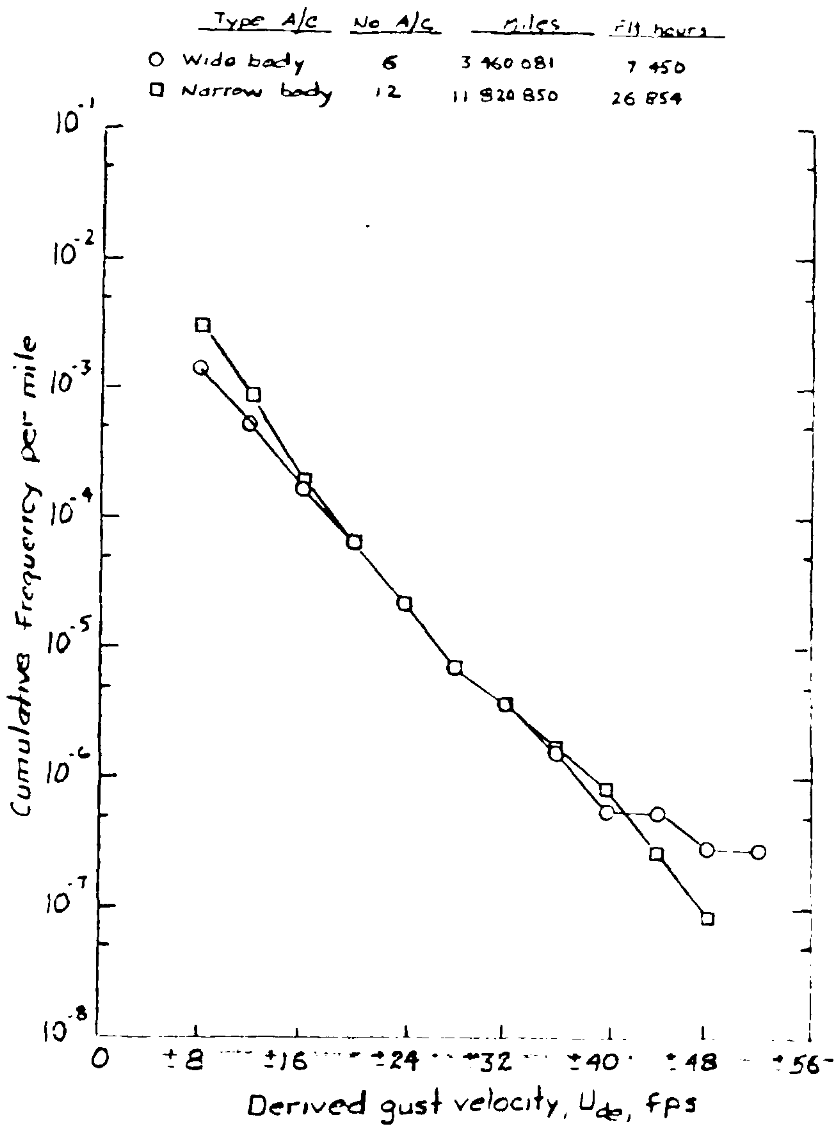


COMPARISON OF GUST ACCELERATIONS FOR WIDE AND NARROW-BODY JET TRANSPORTS

Aircraft type	No A/C	Miles	Flt. hours
○ Wide body	6	3 460 081	7 450
□ Narrow body	12	11 820 850	26854



COMPARISON OF Derived GUST Velocities For WIDE AND NARROW-BODY JET TRANSPORTS



CONCLUSIONS

1. COMPETITIVE AEROBATIC AND INSTRUCTIONAL AIRPLANES REACH OR EXCEED THE DESIGN DIVING SPEED MORE FREQUENTLY THAN AIRPLANES IN OTHER TYPES OF OPERATIONS.

2. AVERAGE FLIGHT ALTITUDES FOR PISTON-POWERED AIRPLANES ARE BELOW 7,000 FT AND MAXIMUM ALTITUDES DO NOT EXCEED 15,000 FT.

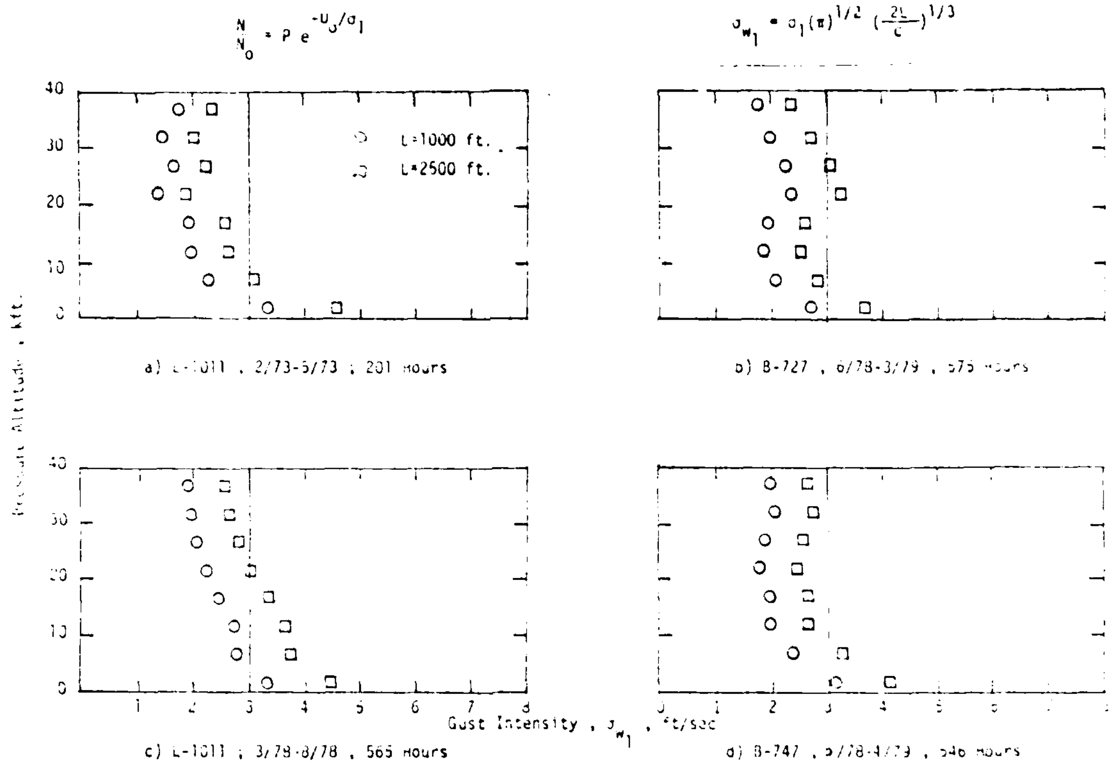
3. THE MOST SEVERE OVERALL IN-FLIGHT LOADS ARE RECORDED BY AIRPLANES FLOWN IN COMPETITIVE AEROBATICS, AND IN PIPELINE PATROL OPERATIONS OVER MOUNTAINOUS REGIONS.

4. THE FREQUENCY OF OCCURRENCE OF GIVEN GUST ACCELERATIONS VARIES BY AS MUCH AS THREE ORDERS OF MAGNITUDE BETWEEN AIRPLANES FLOWN IN DIFFERENT OPERATIONS.

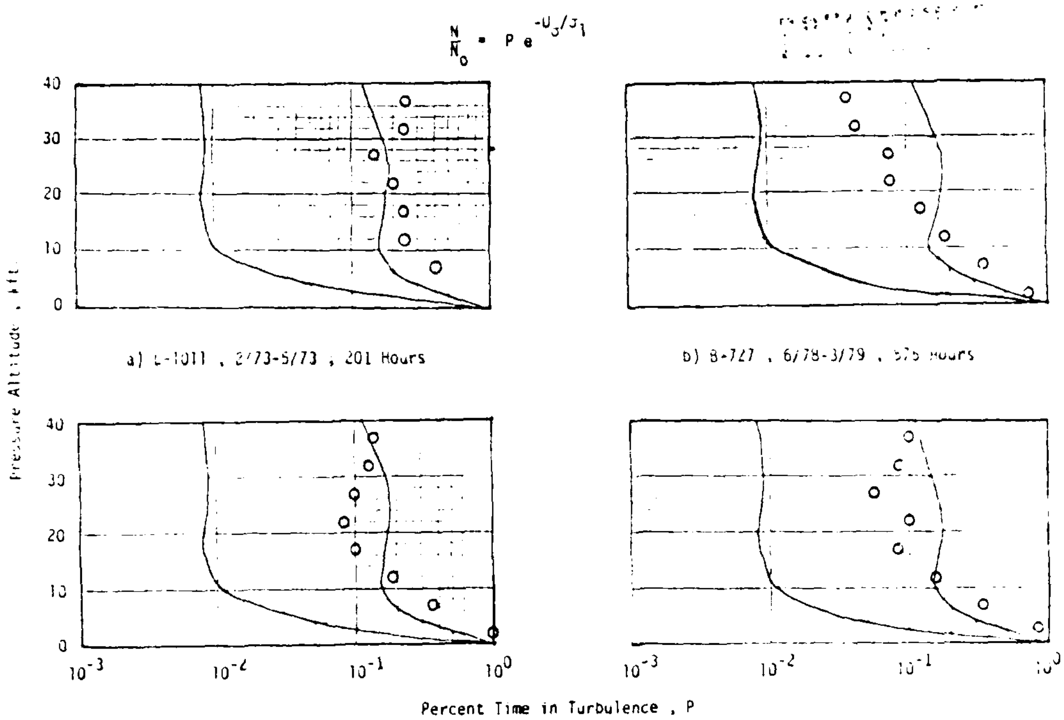
5. THE MOST SEVERE DERIVED GUST VELOCITIES FROM THE STANDPOINT OF MAGNITUDE AND FREQUENCY OF OCCURRENCE WERE EXPERIENCED BELOW 10,000 FT.

6. THE MOST SEVERE MANEUVER LOADS WERE EXPERIENCED BY AIRPLANES FLOWN IN AERIAL APPLICATIONS, COMPETITIVE AEROBATICS, AND INSTRUCTIONAL OPERATIONS.

7. GENERAL AVIATION AIRPLANES ARE FLOWN CLOSER TO THE DESIGN FLIGHT ENVELOP THAN COMMERCIAL TRANSPORT AIRPLANES.



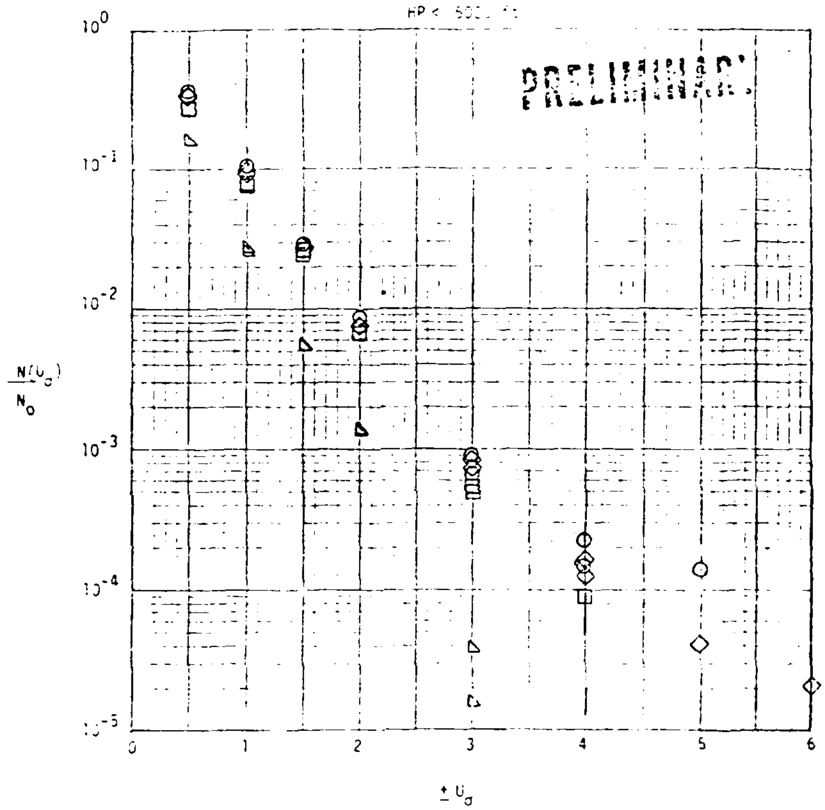
DVGH GUST INTENSITY CALCULATIONS



c) L-1011 , 3/78-8/78 , 565 Hours

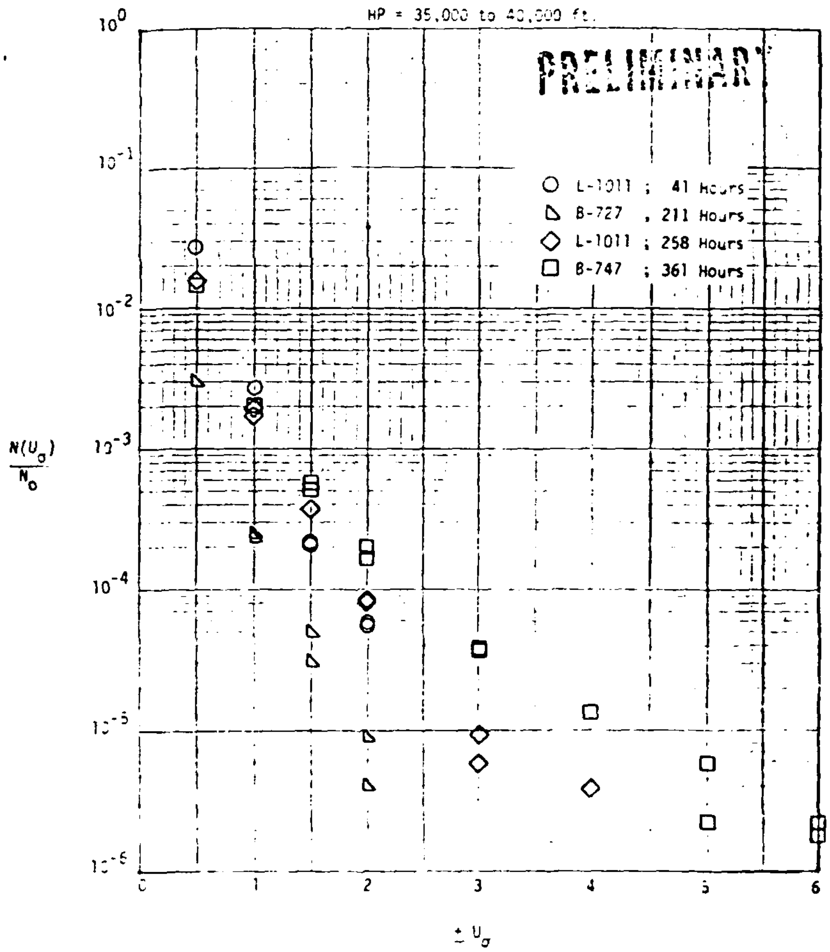
d) B-747 , 5/78-4/79 , 546 Hours

DVGH PERCENT TIME IN TURBULENCE CALCULATIONS



Symbol	○	□	◇	△
Aircraft	L-1011	B-747	L-1011	B-727
Period	2/73-5/73	5/78-4/79	3/76-8/73	6/78-3/79
Hours	13	21	41	35
Route	Eastern U.S. and Carribean	Southern Canada, Continental U.S. Transatlantic	Eastern U.S. and Carribean	Southern Canada and Continental U.S.

COMPARISON OF NORMALIZED LEVEL-CROSSING COUNTS PER SECOND



[illegible] COMPARISON OF NORMALIZED LEVEL-CROSSING COUNTS PER SECOND

NASA LANGLEY RESEARCH CENTER

STORM HAZARDS PROGRAM

MARCH 1981

NLCRABILL - 1

NASA STORM HAZARDS PROGRAM

O PROGRAM ORIGINATED IN 1977 IN RESPONSE TO:

- o NTSB REVIEW CALLING FOR "MORE SOPHISTICATED MEASUREMENT OF THUNDERSTORM AND TURBULENCE"
- o ALPA CALL FOR "REALISTIC POLICIES FOR FLIGHT OPS IN SEVERE STORM AREAS"
- o *NASA ASSESSMENT OF LIGHTNING HAZARD*
  - . NON-METALLIC STRUCTURES
  - . DIGITAL AVIONICS AND CONTROLS
  - . DATA NEEDED AT FLIGHT ALTITUDES

O EVOLVED BROAD SCOPE PROGRAM IN RESPONSE

- o HAZARD PREDICTION, DETECTION, AND AVOIDANCE; DESIGN CRITERIA FOR UNAVOIDABLE HAZARDS
- o HAZARDS OF RAIN, HAIL, WIND SHEAR, TURBULENCE, AND LIGHTNING

LARC STORM HAZARDS PROGRAM MATRIX

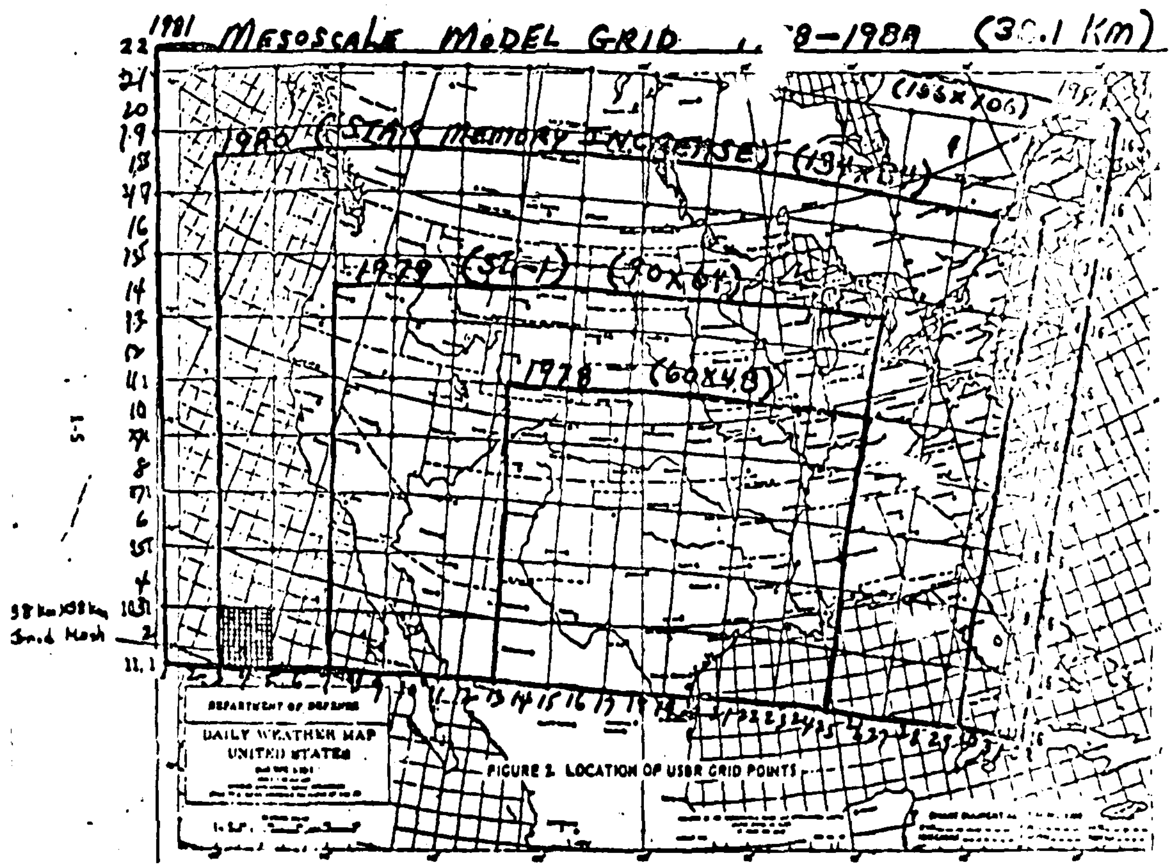
	PRECIP	WIND SHEAR	TURBULENCE	[illegible]
PREDICTION	←	COMPUTER FORECASTING	→	
DETECTION	• EFFECTS OF RAIN LAYER ON AIRBORNE RADOME PERFORMANCE	• GROUND-BASED DOPPLER RADAR MEASUREMENTS CORRELATION WITH AIRBORNE TRUTH MEASUREMENTS OF WIND AND TURBULENCE • AIRBORNE DOPPLER RADAR MEASUREMENTS AND CORRELATION WITH AIRBORNE AND GROUND MEASUREMENTS		• STORM[illegible] • LDAR • ATMOS. [illegible]RY • X-RAY • OPTICAL [illegible]URE
DESIGN	• EFFECTS OF RAIN LAYER ON AIRCRAFT AERODYNAMICS ?	• AIRBORNE INS-TAS DIFFERENCING ON TAKE-OFF AND LANDING • TWA • F-106	• AIRLINER GUST AND MANEUVER LOADS (DIGITAL VGH PROGRAM)	• DIRECT [illegible] TRANS[illegible] • COMP[illegible]RIALS • [illegible] o [illegible]
AVOIDANCE	• MAP ALL HAZARDS ON MANY SEVERE STORMS AND REVIEW CURRENT CRITERIA			

• F-106 [illegible] PROGRAM

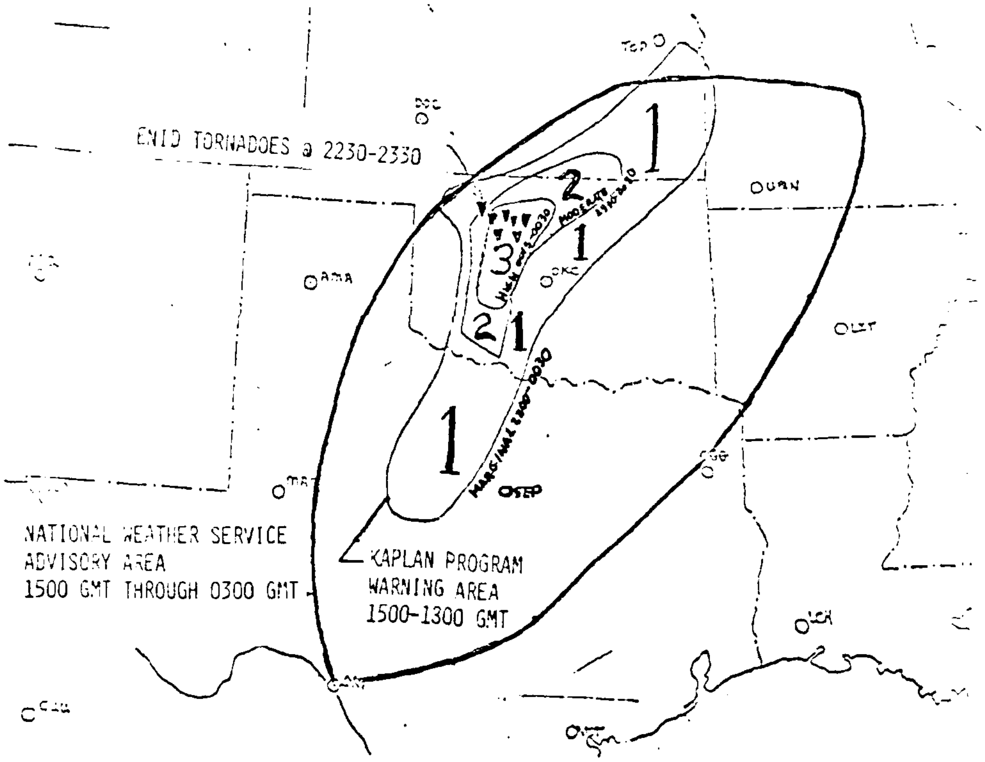
3

COMPUTER FORECASTING SEVERE STORMS

- SEVERE CONVECTIVE STORM MODEL
  - DIFFERENTIAL EQUATIONS OF ATMOSPHERE; HYDROSTATIC
    - 15 LEVELS TO 15 KM
    - 38, 19, AND 9 KM GRID MESH
    - 156 X 106 GRID POINTS (~5900 X 4000 KM)
- COMPUTES DYNAMIC STATE OF ATMOSPHER FOR NEXT 24 HOURS IN 1 MINUTE STE... (USUALLY PLOT AT 1 HOUR INTERVALS)
- OPERATIONAL TEST IN 78, 79, 80
  - 30 - 50 CONSECUTIVE DAYS
  - NATIONAL SEVERE STORMS LAB 80 EVALUATION PROMISING
- FURTHER TESTS PLANNED
  - 1982 MAR - AUG (180 DAYS)
  - GODDARD SPACE FLIGHT CENTER EVALUATION
    - SUBJECTIVE
    - OBJECTIVE



1981 MESOSCALE MODEL GRID
1980 (STAR MEMORY INCREASE) (134X64)
1979 (SL-1) (90X64)
1978 (60X48)
DEPARTMENT OF DEFENSE
DAILY WEATHER MAP
UNITED STATES
FIGURE 2. LOCATION OF USBR GRID POINTS

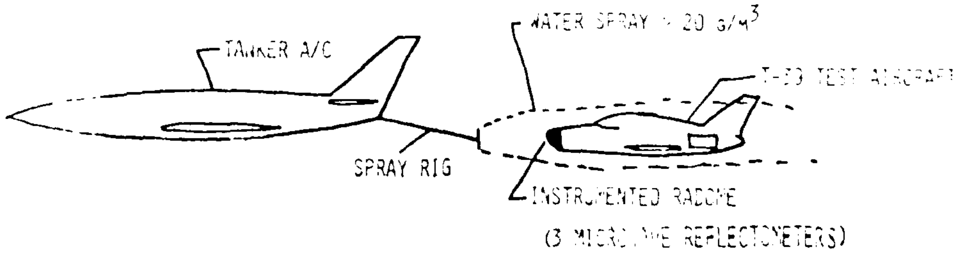


ENID OKLAHOMA - MAY 2, 1979

EFFECTS OF RAIN LAYER ON
AIRBORNE RADOME PERFORMANCE

- 1st ORDER THEORY PREDICTS ~ 15 dBZ LOSS AT 20 g/m^3 & 500 KTS AT X BAND

- FLIGHT TEST PLANNED SUMMER 1981 TO MEASURE WATER LAYER THICKNESS WITH MICROWAVE REFLECTOMETERS - FAA/NASA/USAF



EFFECTS OF RAIN LAYER ON AIRCRAFT AERODYNAMICS

- THEORETICAL STUDY BY U. DAYTON SHOWS @ 500 MM/HR (67.5 dBZ OR 16.5 G/M^3) ON 747 ON APPROACH
  - FILM THICHNESS = .8 MM AVERAGE ON TOP OF WING
  - $\Delta C_{D_{WING}}$ = + 13% DUE TO DROP CRATERING
    + 21% DUE TO WAVINESS } EFFECTS ON ROUGHNESS
- LARC IS INVESTIGATING METHODS OF EXPERIMENTALLY VERIFYING THEORY
  - MEASURE FILM THICKNESS, OR
  - MEASURE INTEGRATED EFFECTS

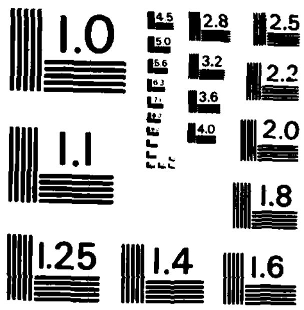
WIND SHEAR

- WIND PROFILES TO 2000 FEET ON TAKE-OFF AND LANDING FROM INS & TAS VELOCITY DIFFERENCING
  - 1082 FLIGHTS FROM TWA 747
  - ALL FUTURE F-106 FLIGHTS

- PROBLEM
  - DEFINE SUITABLE STATISTICAL FORMATS
  - REDUCE PROFILES TO THOSE FORMATS AND PUBLISH

AD-A136 364 REPORT ON A VISIT TO THE USA DURING JANUARY 1982 RELATING TO THE EFFECT O..(U) AERONAUTICAL RESEARCH LABS MELBOURNE (AUSTRALIA) D J SHERMAN AUG 82 2/3

UNCLASSIFIED ARL/STRUC-TM-344-SUPPL F/G 4/2 NL

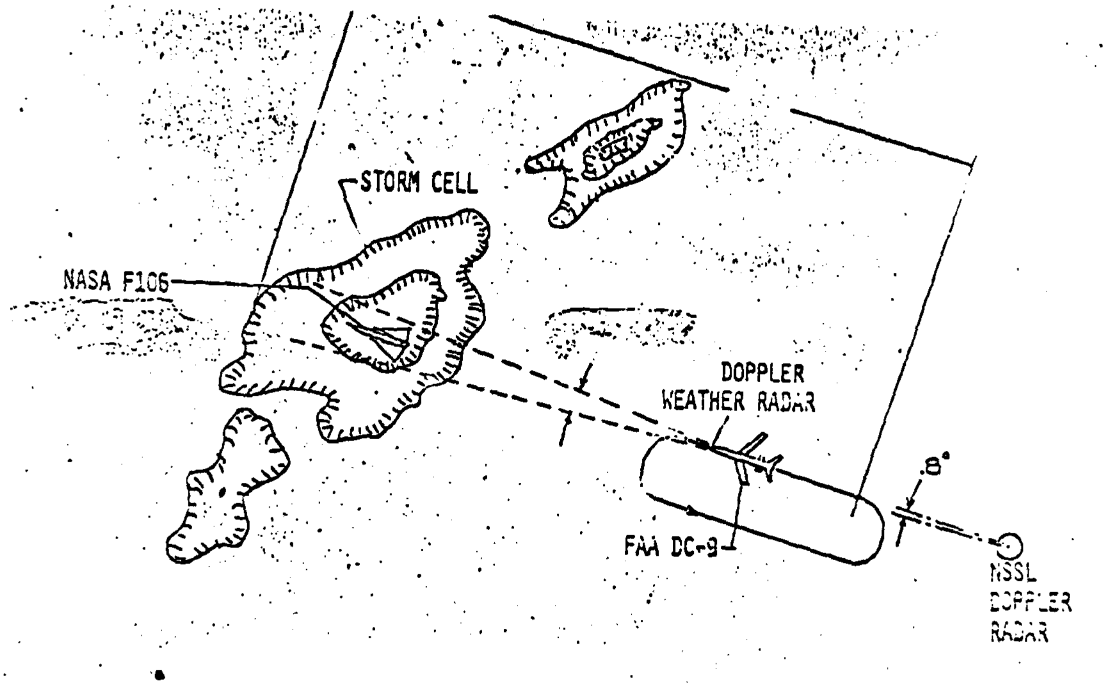


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

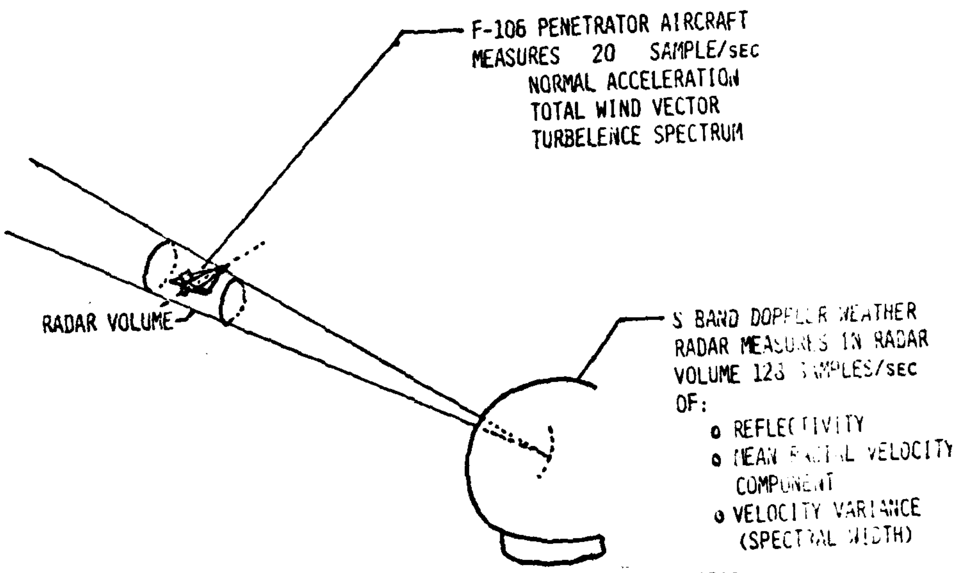
AIRLINER GUST AND MANEUVER LOADS

- PROVIDE DATA FOR DESIGN CRITERIA UPDATING
- GUST EXCEEDANCES DERIVED FROM AIRLINER FLIGHT RECORDER DATA
- RESULTS
  - 1973 DATA ~ 200 HOURS ON L1011 - METHODOLOGY
  - 1978-79 DATA ~ 2000 HOURS ON L1011, B727, B747
  - 1981-82 DATA ~ 2000 HOURS ON DC-10

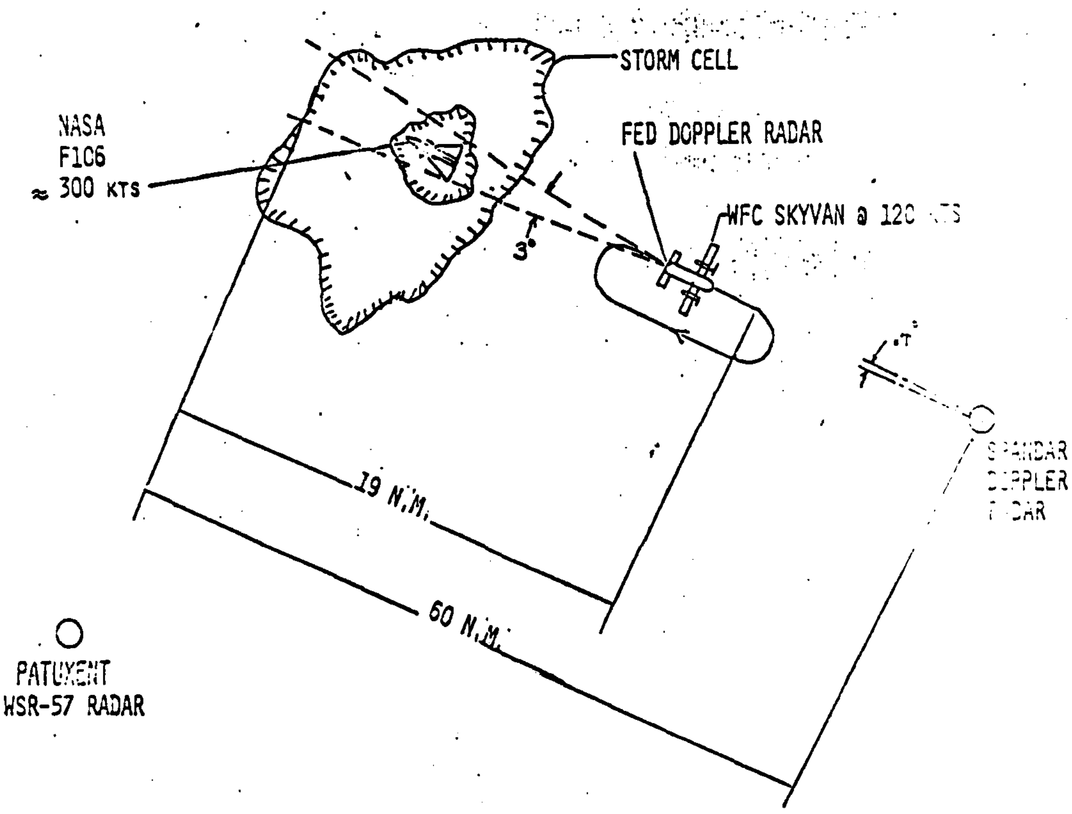


COMMERCIAL "HARD WIRED" DOPPLER WEATHER RADAR
AIRBORNE DOPPLER WEATHER RADAR TEST FOR 1981

GROUND-BASED DOPPLER RADAR MEASUREMENTS
OF WIND AND TURBULENCE WITH F-106



EXPERIMENT WILL DETERMINE CORRELATION OF SPECTRUM WIDTH OVER THE RADAR VOLUME WITH AIRCRAFT MEASUREMENTS OF ATMOSPHERIC TURBULENCE AND NORMAL ACCELERATION RESPONSE



RESEARCH DOPPLER WEATHER RADAR

AIRBORNE DOPPLER WEATHER RADAR TEST FOR 1981

LIGHTNING DETECTION AND HAZARD CORRELATION

- FLIGHT TEST
  - TWIN OTTER 1978 @ NSSL - REPORTED
  - F-106 1979, 1980, 1981 @ NSSL & WFC
- WALLOPS HAS INSTALLED
  - STORMSCOPE (X, Y LIGHTNING LOCATION TO 200 N.MI.)
  - LDAR (X, Y, Z LIGHTNING LOCATION OUT TO 40-50 MILES)
  - ELECTRIC & MAGNETIC FIELD TRANSIENTS TO 30-40 MILES
  - SFERICS DETECTION TO 75-500 MILES
  - SPANDAR
    - . REFLECTIVITY
    - . MEAN WIND
    - . TURBULENCE

    } TO 64 N.MI. @ 1280 PRF
- MEASUREMENTS AND CORRELATION OF LIGHTNING LOCATION, STRENGTH, AND POLARITY WITH RADAR REFLECTIVITY, WIND, AND TURBULENCE CAN BE PERFORMED ROUTINELY EVEN WITHOUT THE F-106 FLIGHT OPERATION

LIGHTNING EFFECTS ON COMPOSITE STRUCTURES
WITH
MATERIALS DIVISION

- OBJECTIVE:
  - PROVIDE TECHNICAL DATA-BASE FOR GENERAL AVIATION DESIGN
  - PROVIDE GUIDELINES FOR DESIGN INCLUDING ELECTRICAL AND FUEL SYSTEMS OF GA AIRCRAFT
  - PROVIDE VERIFICATION PROCEDURES FOR DESIGN EVALUATION
  - DEVELOP NON-DESTRUCTIVE TEST TECHNIQUES

- GROUND TEST - LIGHTNING TECHNOLOGIES INCORPORATED:
  - BONDED METAL STRUCTURES - DUCHESS WING
    CESSNA XOX WING
  - ALL COMPOSITE STRUCTURES - LEAR FAN WING

- FLIGHT TEST - F-106B-COMPOSITE FIN CAP

DIRECT-STRIKE LIGHTNING ELECTROMAGNETIC TRANSIENT EXPERIMENT ON F-106

- PAST LIGHTNING PROTECTION DESIGN BASED ON CLOUD-TO-GROUND DATA DIRECT EFFECTS
- AIRCRAFT STRUCTURES WERE METAL "FARADAY SHIELDS" WITH ANALOG ELECTRONICS, MECHANICAL, AND HYDRAULIC CONTROL SYSTEMS -- DESIGN APPROACHES EVOLVED WITH EXPERIENCE
- FUTURE AIRCRAFT WILL USE MORE COMPOSITE STRUCTURES AND DIGITAL AVIONICS AND FLY-BY-WIRE SYSTEMS
- NEED EXISTS TO MORE ACCURATELY CHARACTERIZE LIGHTNING HAZARD FOR DESIGN PURPOSES AT AIRCRAFT OPERATING ALTITUDES:
  - DIRECT AND NEARBY LIGHTNING STRIKE
  - ASSESSMENT OF INDUCED EFFECTS
  - FREQUENCY-OF-OCCURRENCE DATA
- F-106 AIRCRAFT:
  - INSTRUMENTED TO MEASURE AND RECORD ELECTROMAGNETIC TRANSIENTS
  - PENETRATION OF MODERATE ~ 40 DBZ THUNDERSTORMS
  - CORRELATE WITH GROUND-BASED MEASUREMENTS
- DEVELOP SIMPLIFIED "FREQUENCY-OF-OCCURRENCE" MEASUREMENT SYSTEM FOR FLEET USE

STORM HAZARDS '80 FLIGHT EXPERIMENTS - F-106

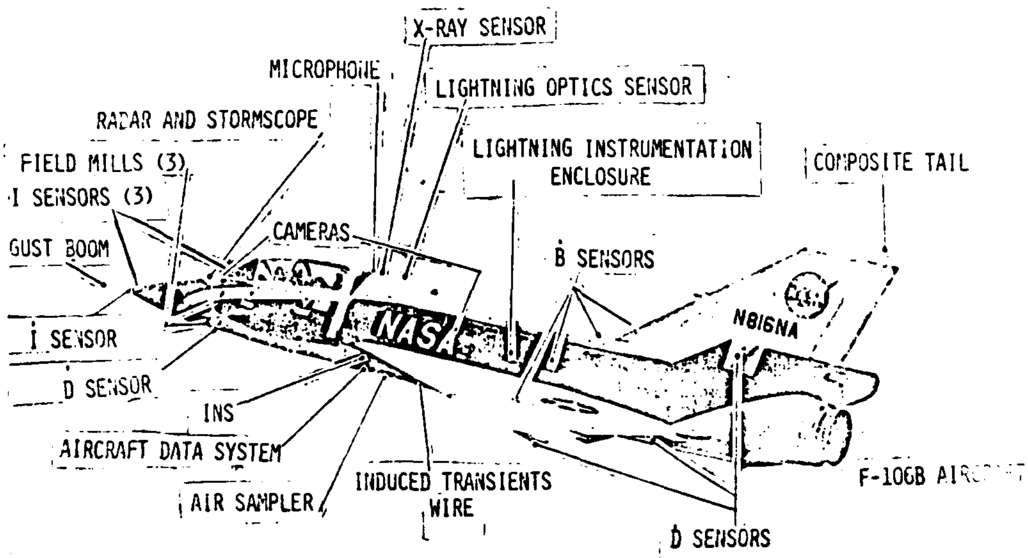
LIGHTNING RELATED:

- DIRECT-STRIKE LIGHTNING (NASA - PITTS)
- LIGHTNING DATA LOGGER (BOEING)
- ATMOSPHERIC CHEMISTRY (NASA - LEVINE)
- LIGHTNING X-RAYS (UNIV. OF WASHINGTON - PARKS)
- LIGHTNING OPTICAL SIGNATURE (NSSL - RUST)
- LIGHTNING STRIKE PATTERNS (NASA - FISHER)
- COMPOSITE FIN CAP (NASA - HOWELL)
- FIELD MILLS (NASA - PITTS)
- CAMERAS (NASA - PITTS)
- INDUCED TRANSIENTS EXPERIMENT (NASA - PITTS)

NON-LIGHTNING RELATED:

- TURBULENCE (NASA - DUNHAM)
- WIND SHEAR (NASA - DUNHAM)
- STORM HAZARDS CORRELATION (NASA - FISHER)

I = STRIKE CURRENT
D = ELECTRIC FLUX DENSITY
B = MAGNETIC FLUX DENSITY



NASA-LANGLEY RESEARCH CENTER STORM HAZARDS RESEARCH VEHICLE

F-106 MISSION SUMMARY
THROUGH SEPTEMBER 10, 1980

	LARC	TIK	ACY	LARC	FERRY	TOTALS
FLIGHTS	5	13	3	14	4	[illegible]
STORM FLIGHTS	0	9	0	11	-	[illegible]
PENETRATIONS	0	32	0	37	-	[illegible]
LIGHTNING:						
DIRECT HITS	0	3	0	7	0	[illegible]
TRANSIENTS	0	2	0	25	0	27
ACE SAMPLES	0	63	0	72	0	[illegible]

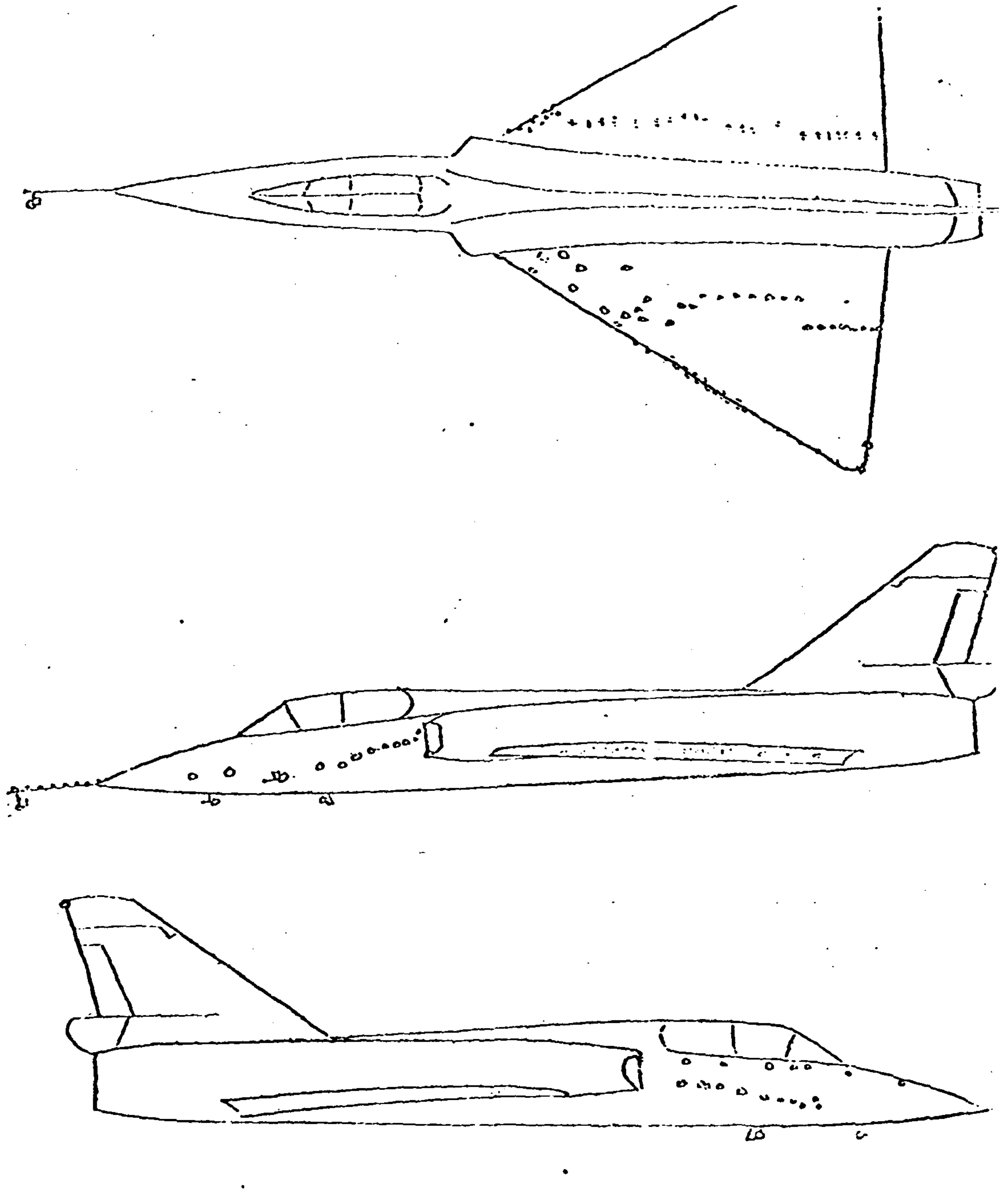
TOTAL FLIGHT TIME 39 HOURS AND 55 MINUTES

SOME PRINCIPAL RESULTS OF 1980 F-106 STORM HAZARDS FLIGHTS

- DIRECT STRIKE LIGHTNING
  - 27 TRANSIENTS OBTAINED
  - MAGNETIC FIELD RATES SMALLER THAN EXPECTED
- ATMOSPHERIC CHEMISTRY EXPERIMENT
  - 116 USEABLE THUNDERSTORM SAMPLES - 34% SHOW ENHANCED N_2O VALUES ABOVE CLEAR AIR
- X-RAY
  - SIGNIFICANTLY ENHANCED COUNTS HAVE BEEN MEASURED FOR THE FIRST TIME AT FLIGHT ALTITUDES - BELIEVED TO BE DUE TO ELECTRON BREMSSTRAHLUNG PROCESS
- COMPOSITE STRUCTURE
  - MINOR DAMAGE TO 5 MIL ALUMINUM COATING IN ONE STRIKE
- LIGHTNING OPTICAL SIGNATURES
  - TRANSIENTS IDENTIFIED - ANALYSIS CONTINUING
- HIT PATTERNS
  - THREE SWEPT STROKES ACROSS WING IN MID SPAN

F-106 LIGHTNING STRIKE PATTERNS

- UNEXPECTED DATA TYPE
- FULL-SCALE, IN-FLIGHT DATA
- SIGNIFICANT TO AIRCRAFT DESIGN = PLATE THICKNESS
- DATA ALREADY BEING APPLIED BY INDUSTRY



• APPROXIMATE LOCATION OF F-106 LIGHTNING HITS

FLIGHTS 018 AND 019, JUNE 17, 1980, OKLAHOMA

THUNDERSTORM TURBULENCE

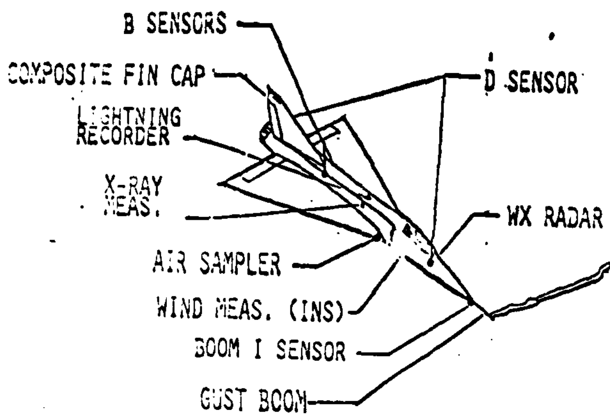
R. E. DUNHAM
(N. L. CRABILL)

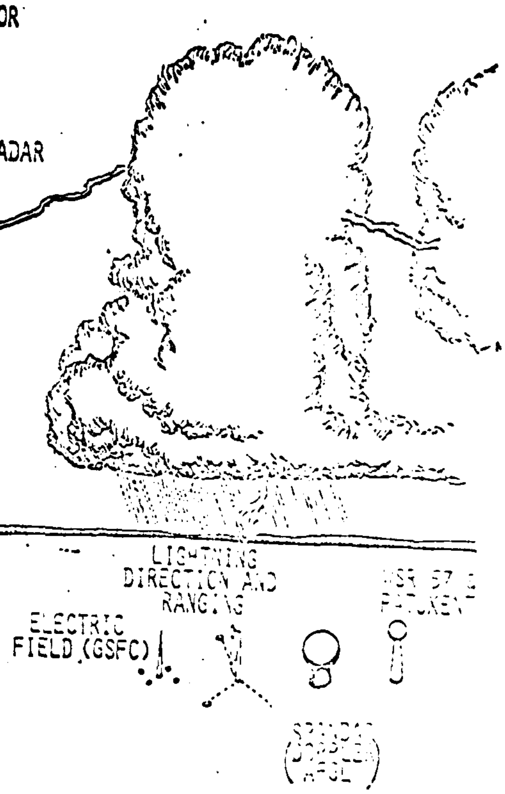
JANUARY 1982

NASA STORM HAZARDS PROGRAM

- T-STORMS MAJOR PROBLEM
  - CURRENT OPERATIONS
    - NTSB - TODD '77
    - ALPA - MUDGE '78
  - NEW TECHNOLOGY AIRCRAFT - LIGHTNING EFFECTS - PLUMER
    - DIGITAL AVIONICS
    - COMPOSITE STRUCTURES

- STORM HAZARDS PROGRAM OBJECTIVES
  - IMPROVE STATE OF THE ART IN DETECTING AND CHARACTERIZING ALL T.STORMS HAZARDS: LIGHTNING, WIND, TURBULENCE, PRECIPITATION
  - IMPROVE UNDERSTANDING OF CURRENT AND FUTURE AIRCRAFT RESPONSE TO T.STORM HAZARDS FOR DESIGN AND OPERATING CRITERIA IMPROVEMENTS
  - RESEARCH MESOSCALE FORECASTING TECHNIQUES USING NUMERICAL MODELING





AIRCRAFT AND INSTRUMENTATION

BOX SCORE			
	1980	1981	GOAL
FLIGHTS	40	48	
PENETRATIONS	69	111	
HITS	10	10	300
TRANSIENTS: NASA	22	32	
BOEING	0	1	

WINDS AND TURBULENCE MEASUREMENTS IN SEVERE STORMS

OBJECTIVES

- o CHARACTERIZE WINDS AND TURBULENCE IN SEVERE STORMS
- o CORRELLATION OF WINDS AND TURBULENCE LEVELS WITH OTHER STORM HAZARDS (LIGHTNING AND PRECIPITATION)
- o PROVIDE DATA FOR EVALUATING REMOTE SENSING METHODS OF TURBULENCE DETECTION
- o PROVIDE WIND FIELD DATA FOR VALIDATING MODELS OF SEVERE STORMS

DATA REDUCTION

AIRSPEED - INERTIAL SPEED = WINDSPEED

$$\left\{\begin{matrix}\text{EULER ANGLE}\\ \text{TRANSFORMATION}\end{matrix}\right\}\left\{\begin{matrix}V\cos\alpha\cos\beta\\ V\sin\beta\cos\alpha\\ V\sin\alpha\end{matrix}\right\}-\left\{\begin{matrix}V_N\\ V_E\\ \int a_z\,dt\end{matrix}\right\}-\left\{\begin{matrix}\text{EULER ANGLE}\\ \text{TRANSFORMATION}\end{matrix}\right\}\left\{\begin{matrix}o\\ lr\\ lq\end{matrix}\right\}=\left\{\begin{matrix}\text{NORTH WIND}\\ \text{SOUTH WIND}\\ \text{VERTICAL WIND}\end{matrix}\right\}$$

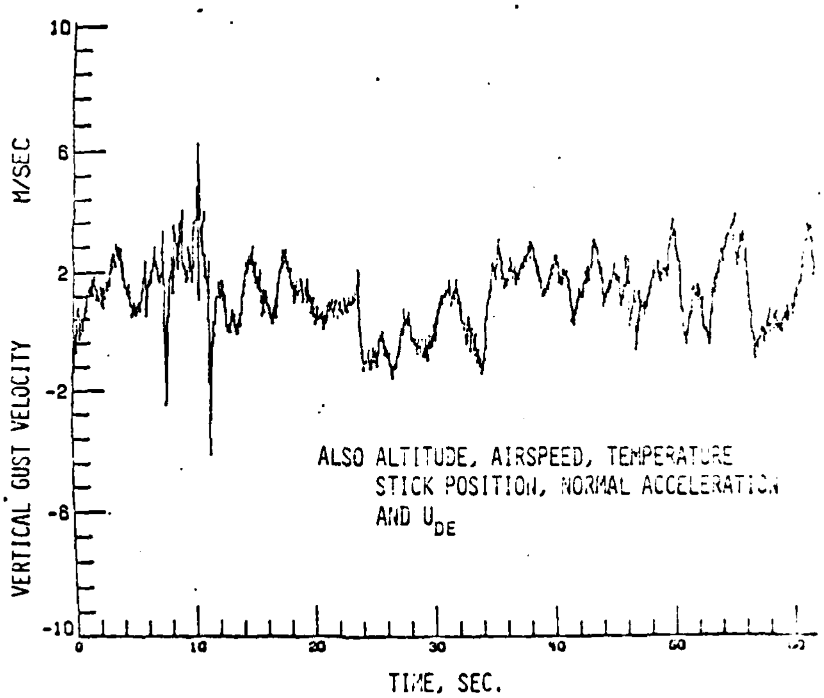
DATA RECORDED ON MAGNETIC TAPE

FREQUENCY RESPONSE GOOD TO 10 HERTZ

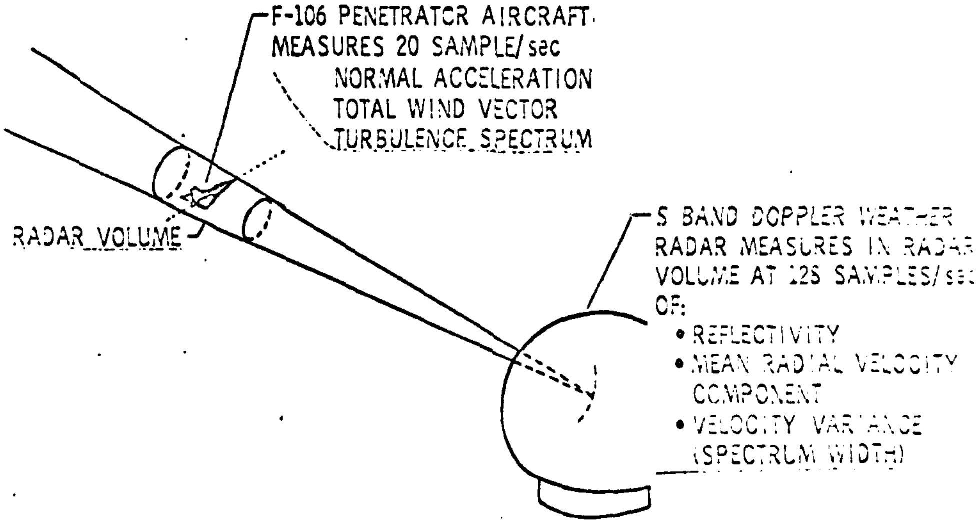
VELOCITIES ACCURATE TO = ± 1% (AIRSPEED 200 M/S)

505-44-13 AVIATION METEOROLOGY RESEARCH-STORM HAZARDS

F.Y. 81 RESULTS F-106 WIND AND GUST TIME HISTORIES-1980 DATA



GROUND-BASED DOPPLER RADAR MEASUREMENTS OF WIND AN TURBULENCE AND CORRELATION WITH F-106 RESULTS

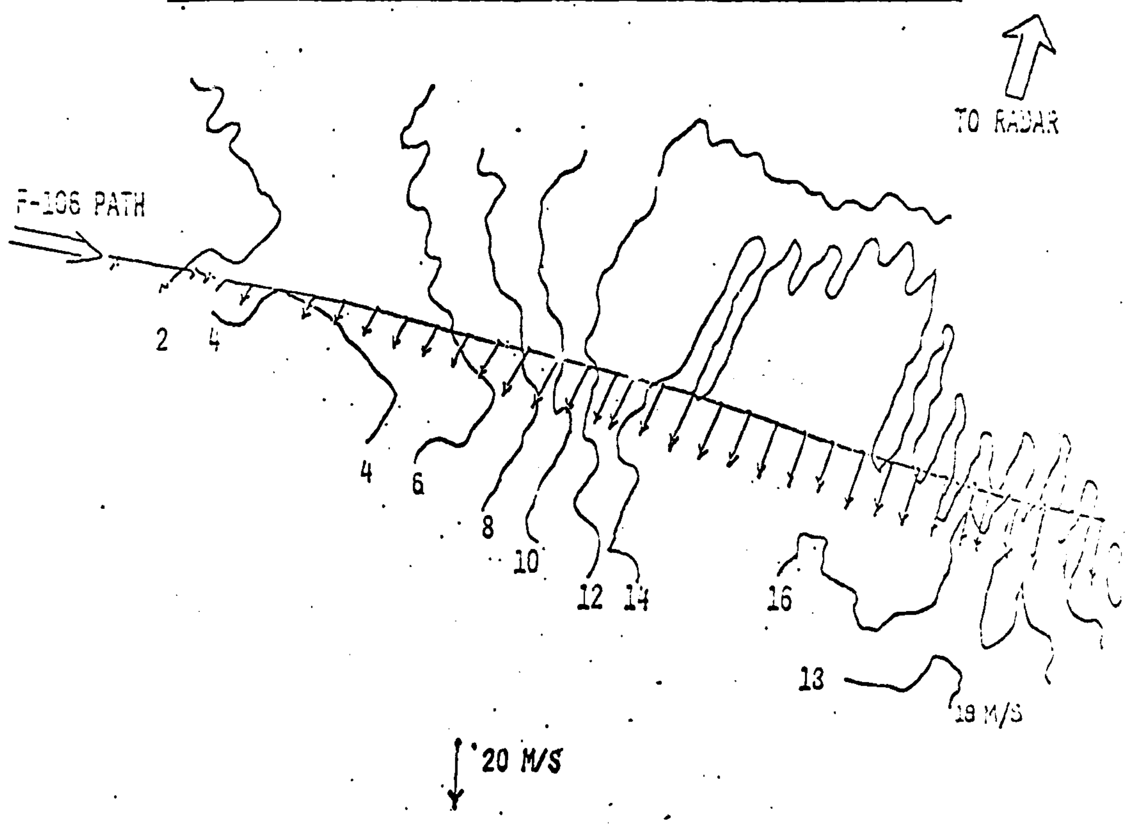


EXPERIMENT WILL DETERMINE CORRELATION OF SPECTRUM WIDTH OVER THE RADAR VOLUME WITH AIRCRAFT MEASUREMENTS OF ATMOSPHERIC TURBULENCE AND NORMAL ACCELERATION RESPONSE

PRELIMINARY THEORY INDICATES TURBULENCE IN PRECIPITATION HAS DIFFERENT POWER SPECTRUM

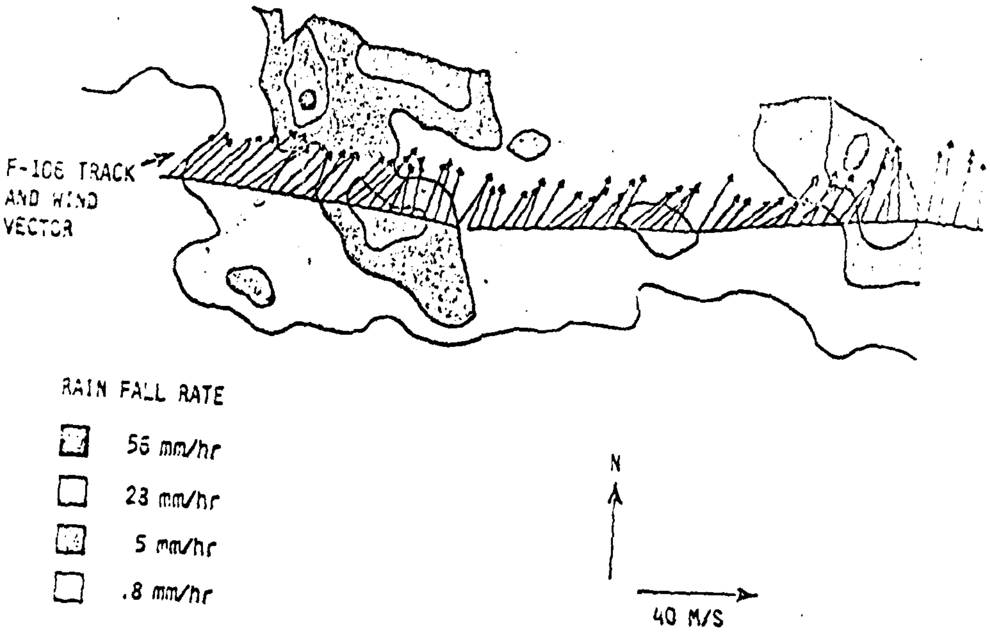
505-44-13 AVIATION METEOROLOGY RESEARCH-STORM HAZARDS

F.Y. 81 RESULTS   WIND   GROUND BASED DOPPLER WIND-'80 DATA



505-44-13 AVIATION METEOROLOGY RESEARCH-STORM HAZARDS

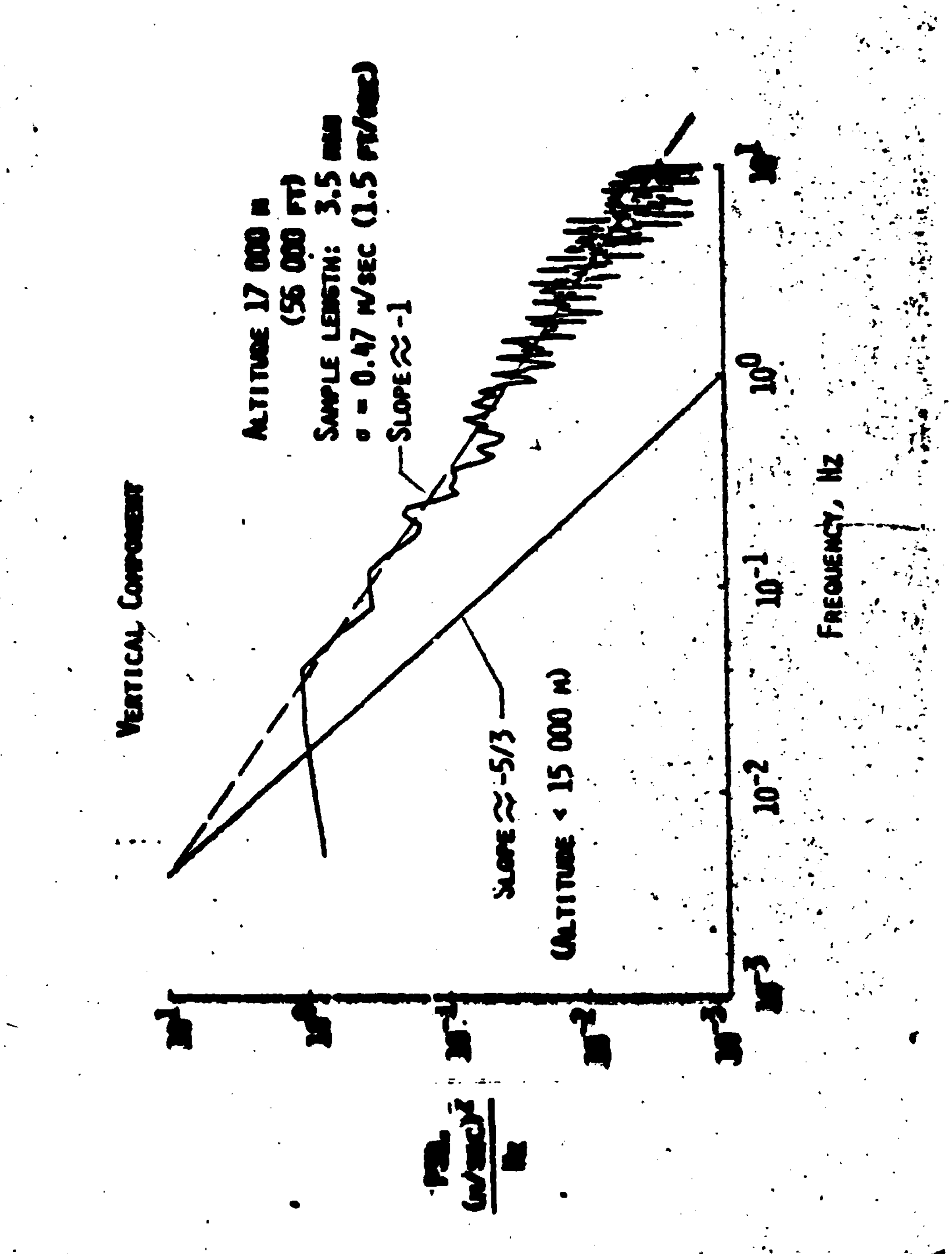
F.Y. 81 RESULTS WIND AND GUST DATA VS RADAR REFLECTIVITY - 1980 DATA



SUMMARY

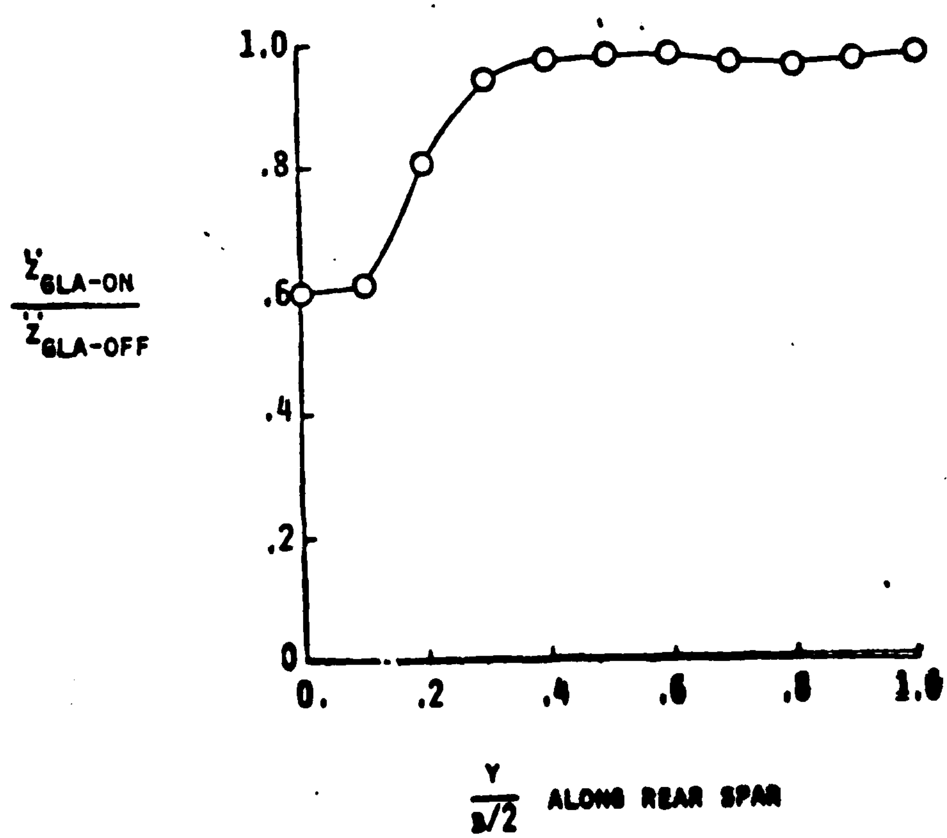
- O IN 1980, 104 MINUTES OF TURBULENCE DATA IN SEVERE STORMS WERE COLLECTED AND TRANSMITTED TO NSSL FOR COMPARISON WITH GROUND BASED STORM MEASUREMENTS (DOPPLER RADAR AND WS-57)
- O IN 1981, 25 THUNDERSTORM FLIGHTS WERE FLOWN WITH USEABLE TURBULENCE DATA. THESE DATA WILL BE REDUCED IN THE COMING YEAR.

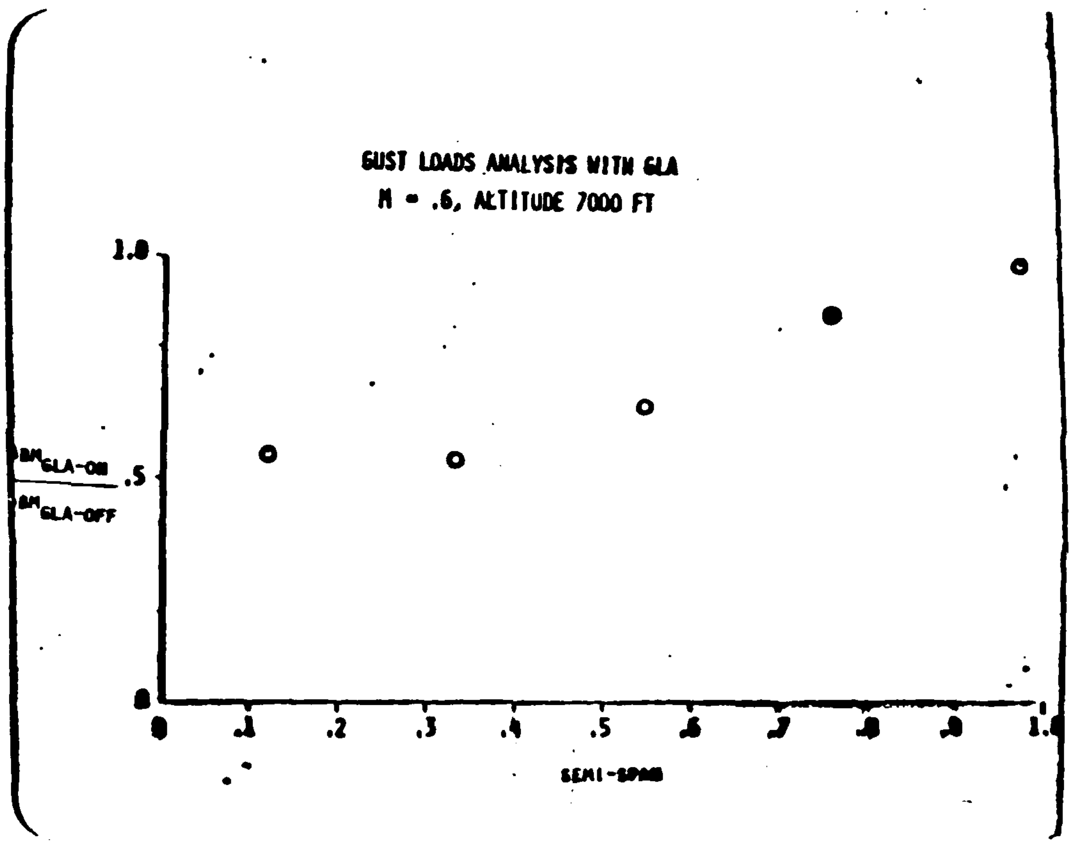
INITIAL SPECTRUM OF HIGH ALTITUDE ATMOSPHERIC TURBULENCE EXHIBITS SURPRISING FEATURE



ANALYSIS OF GLA-SYSTEM USING DYLOFLEX

M = 0.6
ALTITUDE = 7000 FT




GUST LOADS ANALYSIS WITH GLA
M = .6, ALTITUDE 7000 FT
1.0
.5
0
$\frac{BM_{GLA-ON}}{BM_{GLA-OFF}}$
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
SEMI-SPAN

WIND SHEAR

R. E. DUNHAM
(N. L. CRABILL)

JANUARY 1982

IN-FLIGHT WIND SHEAR ENCOUNTERS

OBJECTIVES:

DETERMINE THE FEASIBILITY OF OBTAINING AIRBORNE MEASUREMENTS OF WINDS AND WIND SHEARS FROM COMMERCIAL OPERATIONS DURING LANDINGS AND TAKEOFFS

APPROACH:

OBTAIN DATA FROM A COMMERCIAL AIR CARRIER OPERATING AIRPLANES EQUIPPED WITH INERTIAL NAVIGATION SYSTEMS AND DIGITAL FLIGHT DATA RECORDERS

METHOD:

OBTAINED 2 WEEKS OF DATA IN THE SPRING OF 1977 ON A U.S. AIR CARRIER (TWA) EQUIPPED WITH DFDR-AIDS AND INS

DATA RECORDED:

TRUE AIRSPEED
ANGLE OF ATTACK
RADAR ALTIMETER
TIME
HEADING
LATITUDE
LONGITUDE
DRIFT ANGLE
GROUNDSPEED
PITCH ATTITUDE
ROLL ATTITUDE

DATA REDUCTION

HORIZONTAL WIND IS THE DIFFERENCE BETWEEN THE TRUE AIRSPEED AND THE GROUNDSPEED. WIND VECTOR IS BROKEN INTO COMPONENTS ALONG THE NORTH-SOUTH AND EAST-WEST DIRECTIONS.

$$\text{NORTH-SOUTH} = V_{\text{GROUNDSPEED}}\,\text{COS(HEADING+DRIFT ANGLE)} - V_{\text{AIRSPEED}}\,\text{COS(PITCH ATTITUDE-AOA)COS(HEADING)}$$

$$\text{EAST-WEST} = V_{\text{GROUNDSPEED}}\,\text{SIN(HEADING+DRIFT ANGLE)} - V_{\text{AIRSPEED}}\,\text{COS(PITCH ATTITUDE-AOA)SIN(HEADING)}$$

DATA BASE

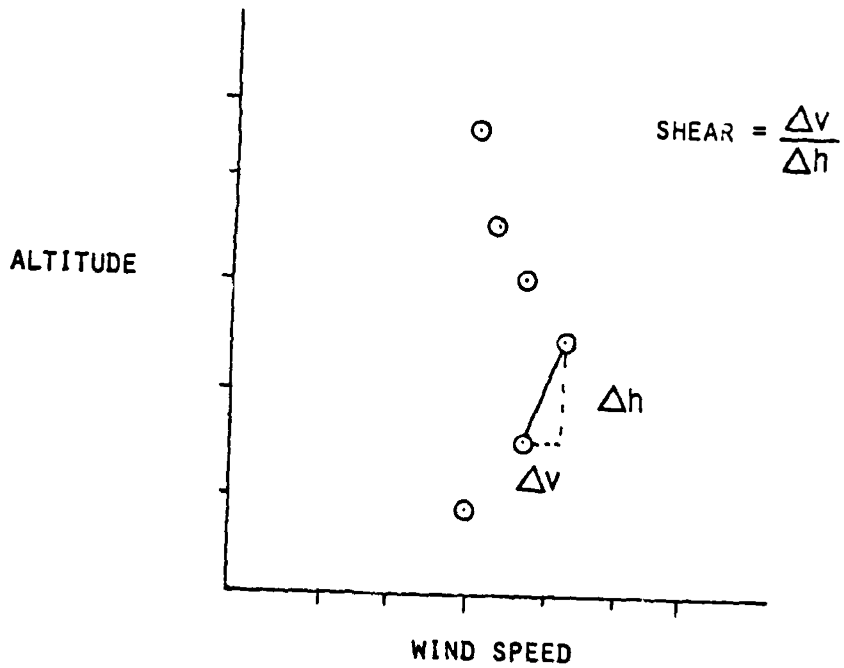
9 HOURS DATA

OVER 640 OPERATIONS (LANDINGS OR TAKEOFFS)

14 AIRPORTS

60% OF THE DATA OBTAINED AT LONDON, NEW YORK, ATLANTIC CITY, AND NEW JERSEY

WIND SHEAR


SHEAR = $\frac{\Delta v}{\Delta h}$
ALTITUDE
Δh
Δv
WIND SPEED

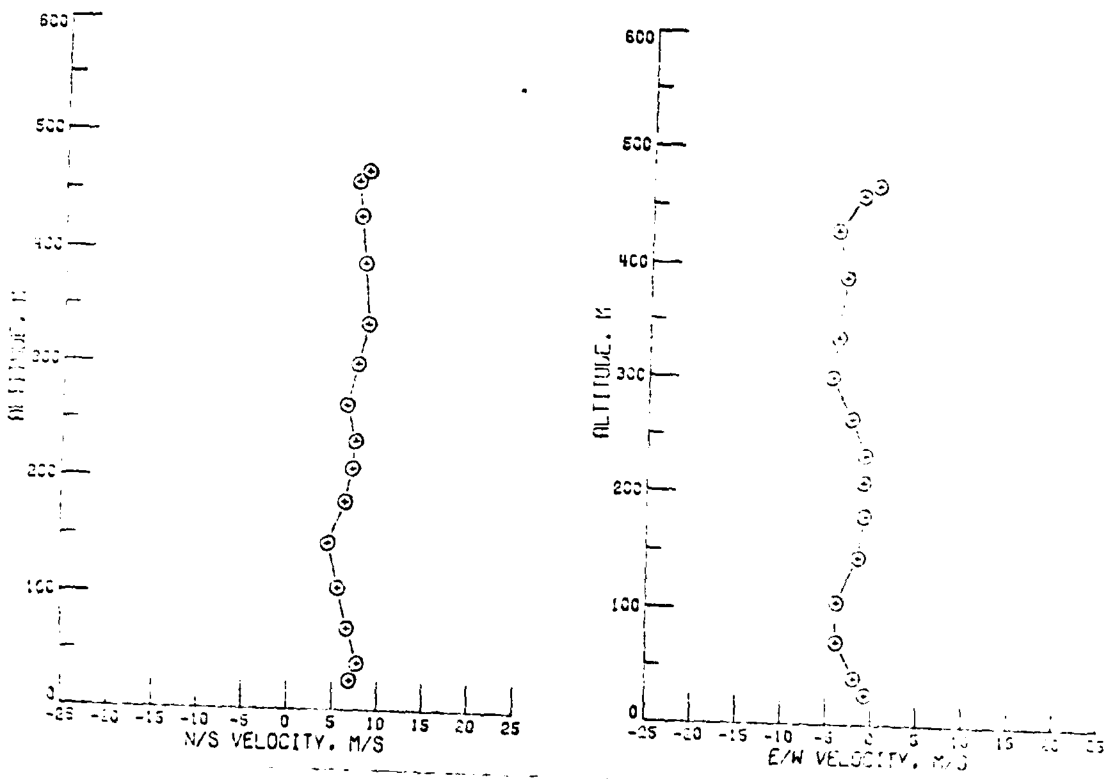


Figure 1.- Typical measurement of North/South and East/West wind components as a function of altitude for a take-off.

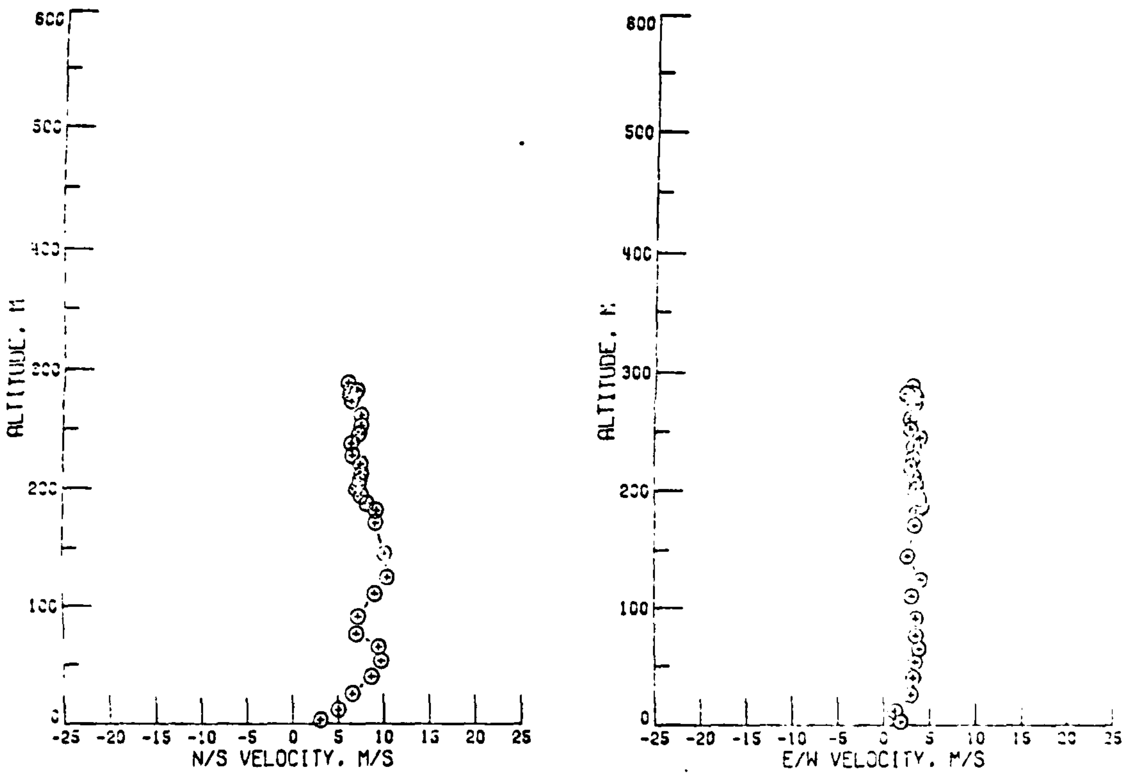


Figure 2.- Typical measurement of North/South and East/West wind components as a function of altitude for a landing.

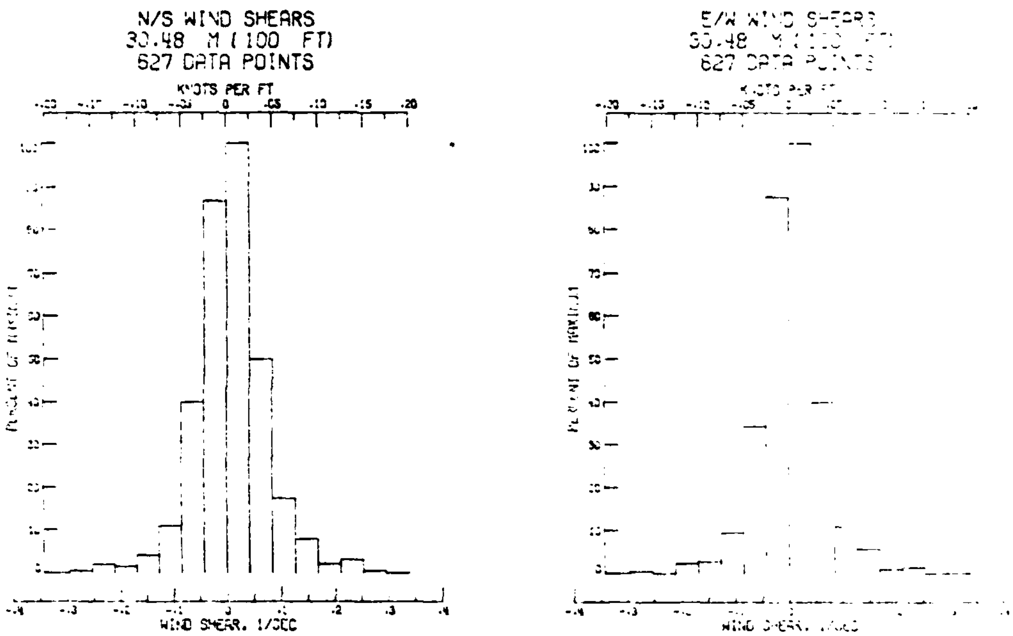


Figure 3.- Distribution of North/South and East/West wind shears in 100 ft (30.48m) altitude increments.

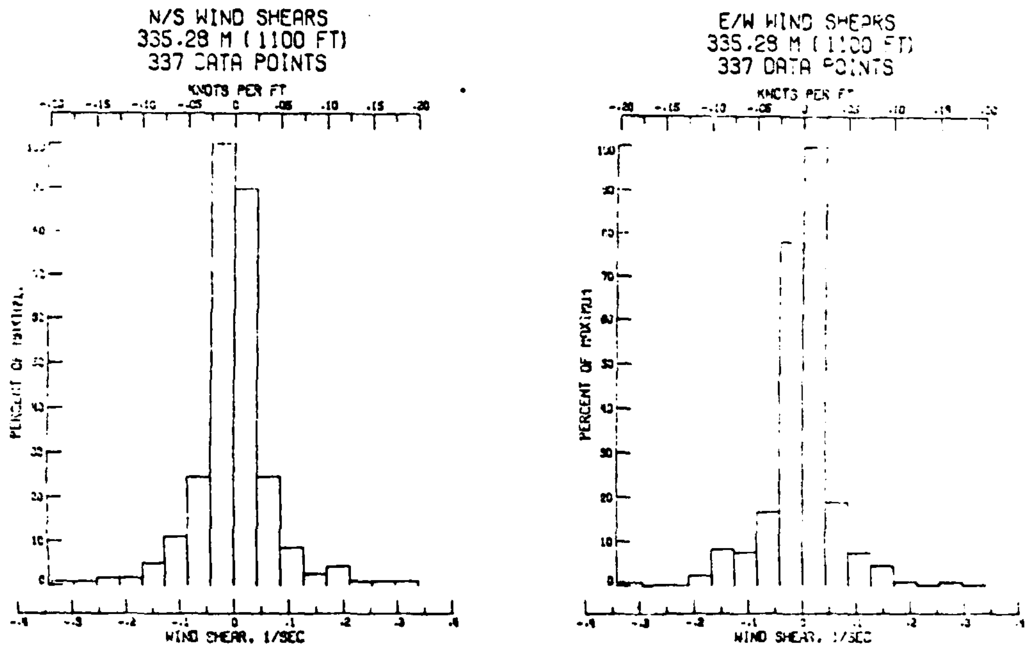
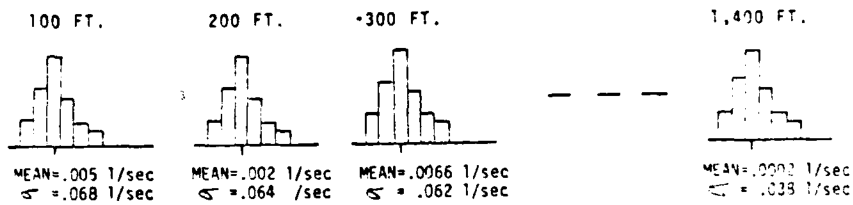


Figure 3.- Continued



- FOR ALL ALTITUDES THE MEAN IS APPROXIMATELY 0, AND THE STANDARD DEVIATION IS .07 1/SEC (4.1 KNOTS/100 FT.)

- FOR ALL ALTITUDES THE VARIATION IN THE STANDARD DEVIATION IS SMALL, APPROXIMATELY .008 1/SEC (.47 KNOTS/100 FT.)

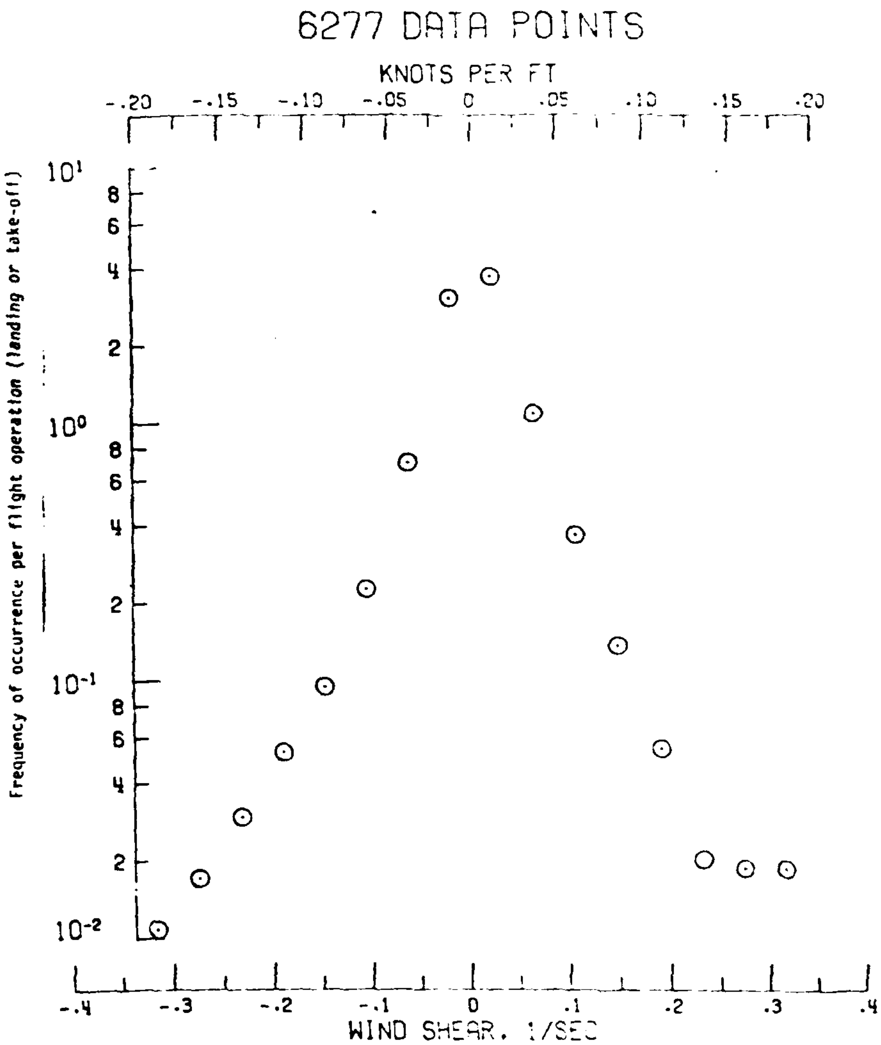


Figure 8.- Frequency of occurrence of wind shear per landing or take-off.

CONCLUDING REMARKS

- AN EXTENSIVE DATA BASE COULD BE CONSTRUCTED FROM DATA PRESENTLY BEING RECORDED BY COMMERCIAL AIRPLANE OPERATORS

- A GIVEN MAGNITUDE WIND SHEAR IS EQUALLY LIKELY TO OCCUR AT ANY ALTITUDE (LESS THAN 1,800 FEET)

WIND HAZARD MODELS
FOR
PILOTED AIRCRAFT SIMULATIONS

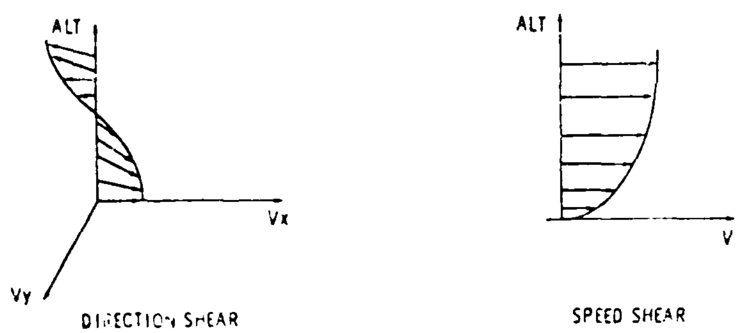
ROLAND L. BOWLES
ACD/ASB

SIMULATION OF WIND SHEARS AND TURBULENCE

- WIND SHEAR DEFINITION (8TH. ICAO AIR NAV. CONF. 1974)

  "CHANGE IN WIND VECTOR IN A RELATIVELY SHORT AMOUNT OF SPACE"

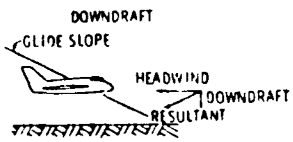
DEFINITION OF WIND SHEAR

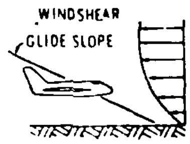


- FOR AVIATION PURPOSES WE ARE INTERESTED IN WIND VARIATION ALONG THE FLIGHT PATH OF AN AIRCRAFT.

THE HAZARD

- WIND SHEARS AND DOWNDRAFTS ENCOUNTERED DURING TAKEOFF AND LANDING POSE SERIOUS AVIATION HAZARDS.





- FOR A SWEPTWING TRANSPORT A 5 KNOT DOWNDRAFT IS COMPARABLE IN SEVERITY TO A 5 KNOT PER HUNDRED FEET SHEAR.

- AIRCRAFT ACCIDENTS
  - MAJOR FACTOR IN 39 PERCENT OF ALL FATAL AIRCRAFT ACCIDENTS BETWEEN 1964-1973 (FAA-RD-77-36)
  - RECENT ACCIDENTS

    IBERIAN DC-10, DECEMBER 1973, LOGAN

    CONTINENTAL 727, AUGUST 1975, DENVER

    EASTERN 727, JUNE 1975, JFK

    ALLEGHENY DC-9, JUNE 1976, PHILADELPHIA

    SOUTHERN DC-9, APRIL 1977, NEW HOPE, GEORGIA

THE EFFECT OF WIND SHEAR

- AIRCRAFT PHUGOID STABILITY ADVERSELY EFFECTED
- WIND SHEAR HAS LITTLE EFFECT ON SHORT PERIOD MOTION
- USE FULL PARAMETER FOR ANALYSIS

$$\sigma = \frac{V_A}{g} \cdot \text{WIND GRADIENT}$$

TABLE II.- EFFECT OF POSITIVE AND NEGATIVE SHEAR ON PHUGOID MODE - BASIC AIRPLANE

[δ_f = 0.4363 rad; σ_w = 0.0]

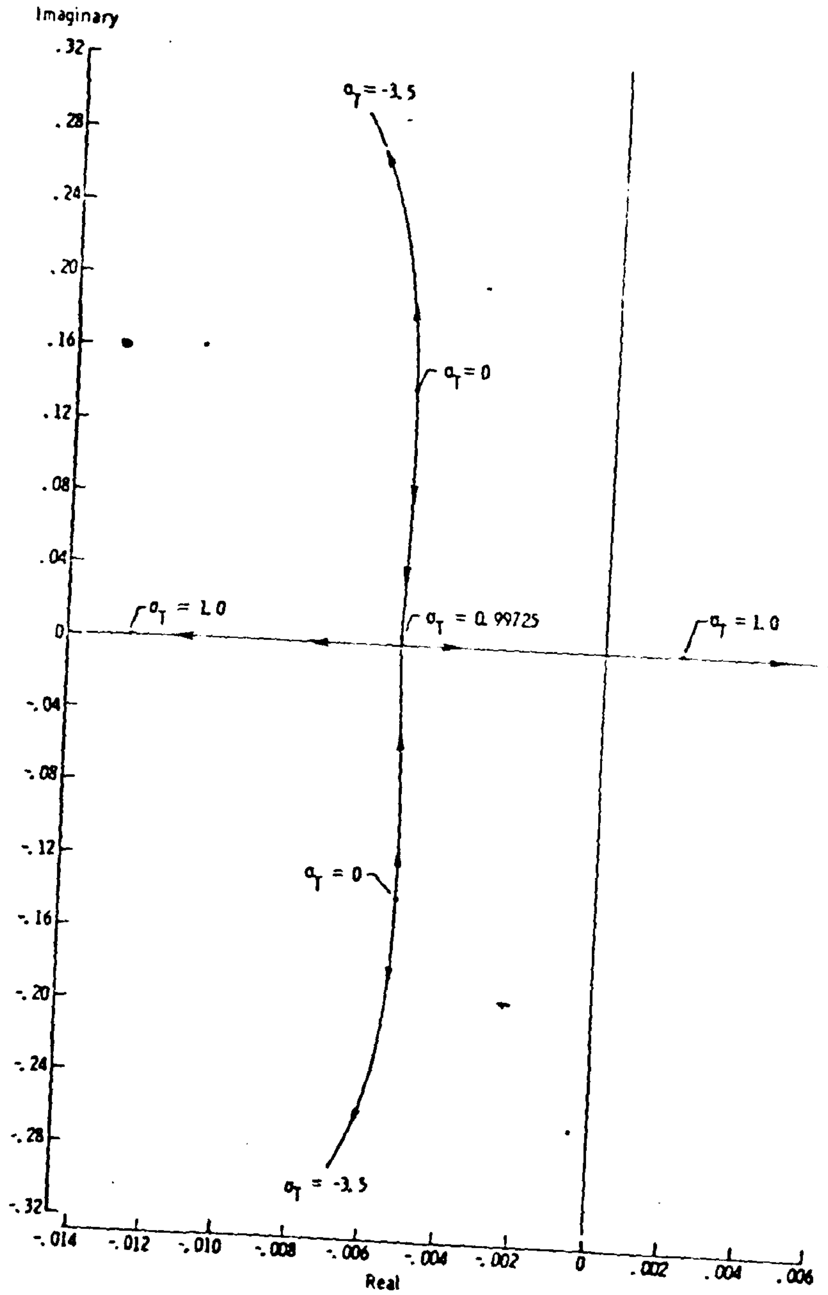
Γ_0, rad	σ_u	Roots		$T_{1/2}$, sec	T_{double}, sec	P, sec	ω_p, rad	ζ_p
0.0	0.0	-0.002954	±0.140281	234.59	------	44.79	0.14031	0.021
-.05236	.0	-.0052453	±.140501	132.09	------	44.72	.1406	.037
	-.5	-.0052994	±.171476	130.77	------	36.64	.1716	.031
	-1.0	-.0054139	±.197251	128.00	------	31.85	.1973	.027
	-1.5	-.0055879	±.219691	124.02	------	28.60	.2198	.025
	-2.0	-.0058200	±.239741	119.07	------	26.21	.2398	.024
	-2.5	-.0061076	±.257[illegible]1	113.47	------	24.36	.2580	.024
	-3.0	-.0064496	±.274751	107.45	------	22.87	.2748	.023
	-3.5	-.0068442	±.290321	101.25	------	21.64	.2904	.023
	.5	-.0052567	±.0996191	131.83	------	63.07	.9962	.00528
	1.0	-.012747	.0020821		332.84	-----	------	-------
	1.5	-.10647	.095524		7.25	-----	------	-------
	2.0	-.14893	.13756		5.04	-----	------	-------
	2.5	-.18207	.17013		4.07	-----	------	-------
	3.0	-.21051	.19785		3.50	-----	------	-------
	3.5	-.23600	.22249		3.11	-----	------	-------

$\sigma > 0$ (DECREASING HEAD WIND) HW $\longrightarrow$ TW

$\sigma < 0$ (DECREASING TAIL WIND) TW $\longrightarrow$ HW

FOR TYPICAL JET TRANSPORT WITH APPROACH SPEED 120 KIAS

$$-4 \leq \sigma \leq 4$$



Root-locus plot for the phugoid mode $\Gamma_0 = -0.05236$ radian; $\sigma_w = 0$; $\sigma_T = \sigma_u$.

ON-GOING PROGRAMS

- FAA WIND-HAZARD PROGRAM (FAA-ED-15-2)
  - WIND SHEAR CHARACTERIZATION
  - HAZARD DEFINITION
  - GROUND-BASED WIND SHEAR DETECTION SYSTEMS
  - AIRBORNE WIND SHEAR DETECTION EFFORTS
  - WIND SHEAR DATA MANAGEMENT
  - INTEGRATION OF WIND SHEAR SYSTEMS AND DATA INTO NATIONAL AIRSPACE SYSTEM (NAS)
- NASA TCV PROGRAM
  - AIRBORNE WIND SHEAR DEVELOPMENT EFFORTS
    - ENERGY SENSOR
    - ON-LINE SHEAR ESTIMATION AND CONTROL
    - DISPLAY OF WIND HAZARD IN COCKPIT

PROPOSED FAA "STANDARD BENCH MARK"

- FAA/SRI WIND HAZARD PACKAGE
  - 21 WIND HAZARD PROFILES REPRESENTING
    - NEUTRAL
    - NIGHTTIME STABLE
    - FRONTALS
    - THUNDERSTORMS

    ATMOSPHERIC CONDITIONS
  - EACH PROFILE COMPRISED OF THREE AXIS
    - MEAN WIND SPECIFICATIONS
    - TURBULENCE SPECIFICATIONS

      DRYDEN MODEL
  - EACH PROFILE GIVEN AS A FUNCTION OF ALTITUDE AND RANGE FROM TOUCHDOWN

TABLE 1.- WIND PROFILES CROSS REFERENCE GUIDE

Profile Label	Relative Wind Profile Severity	Source of Wind Data	Atmospheric Condition
	Approach		
B1/D1	Low	Meteorological math model	Neutral
B2	Low	Meteorological math model	Nighttime stable
B3	Low	Meteorological math model	Nighttime stable
B4	Low	Tower measurements	Nighttime stable
B5/D5	Low	Logan accident reconstruction	Warm front
B6	Low	Same as B5, rotated 40^0	Warm front
B7/D7	Moderate	Tower measurements	Thunderstorm
B8/D8	Moderate	Tower measurements	Thunderstorm
D2	Moderate	Tokyo accident reconstruction	Warm front
B9/D9	Moderate	Tower measurements	Cold front
B10	Moderate	Philadelphia accident reconstruction	Thunderstorm
B11	Moderate	Kennedy accident reconstruction	Thunderstorm
B12/D6	High	Kennedy accident reconstruction	Thunderstorm
D10	High	Kennedy accident reconstruction	Thunderstorm
D4	High	Philadelphia accident reconstruction	Thunderstorm
D3	High	Mathematical model	Thunderstorm
	Takeoff		
D15	Low	Tower measurements	Cold front
D12	Moderate	Philadelphia accident reconstruction	Thunderstorm
D14	Moderate	Philadelphia accident reconstruction	Thunderstorm
D11	High	Kennedy accident reconstruction	Thunderstorm
D13	High	Philadelphia accident reconstruction	Thunderstorm

TABLE 2.- TURBULENCE SPECIFICATIONS FOR PROFILE D10
(Kennedy/Eastern 66 Accident Reconstruction)

Altitude (meters)	Longitudinal Scale Length (meters)	Lateral Scale Length (meters)	Vertical Scale Length (meters)	Longitudinal RMS (knots)	Lateral RMS (knots)	Vertical RMS (knots)
6.10	32.23	15.15	3.17	3.40	2.70	2.34
30.49	66.07	40.91	16.16	4.05	3.46	3.53
60.98	93.45	65.09	32.32	4.43	3.95	4.35
121.95	132.16	103.54	64.63	4.85	4.50	5.36
182.93	161.86	135.85	96.95	5.11	4.86	6.05
457.32	256.37	251.37	242.47	5.74	5.78	7.94

TABLE I: WIND PROFILES CROSS REFERENCE GUIDE

Profile Label	Relative Severity			Flight Experiment		Atmospheric Condition
	Low	Moderate	High	Landing	Takeoff	
B1	X			X		Neutral
B2	X			X		Nighttime Stable
B3	X			X		Nighttime Stable
B4	X			X		Nighttime Stable
B5		X		X		Frontal
B6		X		X		Frontal
B7		X		X		Thunderstorm
B8		X		X		Thunderstorm
B9			X	X		Frontal
B10			X	X		Thunderstorm
B11			X	X		Thunderstorm
B12			X	X		Thunderstorm
D2		X		X		Frontal
D3			X	X		
D4			X	X		Thunderstorm
D10			X	X		Thunderstorm
D11			X		X	
D12		X			X	
D13			X		X	
D14		X			X	
D15	X				X	

COMPARISON OF WIND HAZARD SPECIFICATIONS

	FAA AC 20-57A	FAA/SRI PACKAGE
LONGITUDINAL TURBULENCE	L_u = 600 FEET σ_u = 0.15 KNOTS	L_u = 65 TO 80,000 FEET σ_u = UP TO 7.93 KNOTS
LATERAL TURBULENCE	L_v = 600 FEET σ_v = 0.15 KNOTS	L_v = 49 TO 80,000 FEET σ_v = UP TO 7.93 KNOTS
VERTICAL TURBULENCE	L_w = 30 FEET σ_w = 1.5 KNOTS	L_w = 10 TO 795 FEET σ_w = UP TO 7.94 KNOTS
MEAN WINDS		
LONGITUDINAL	HW-25 KNOTS, TW-10 KNOTS	HW-53 KNOTS, TW-79 KNOTS
LATERAL	CW-15 KNOTS	CW-65 KNOTS
VERTICAL	NOT GIVEN	UD-10 KNOTS, DD-31 KNOTS
WIND SHEARS		
LONGITUDINAL	8 KNOTS/100 FEET	50 KNOTS/100 FEET
LATERAL	FROM 200 FEET	17 KNOTS/100 FEET
VERTICAL	TO TOUCHDOWN	20 KNOTS/100 FEET

RESULTS OF TCV SIMULATION FLOWN AGAINST WIND HAZARD PACKAGE

- MODE OF OPERATION
  - FULL NONLINEAR SIMULATION
  - STRAIGHT-IN APPROACH ($\approx$ 6 MILES OUT)
  - INITIAL TRIM WITH WINDS PRESENT
  - AUTOLAND ENGAGED
  - AUTOTHROTTLE ENGAGED
  - AUTOTHROTTLE INCLUDES A WIND SHEAR DETECTOR (PRESENT STATE OF THE ART)
- SIMULATION FLOWN AGAINST ALL 21 PROFILES
- TOUCHDOWN FOOTPRINT
- ACCEPTABILITY CRITERIA
- ACCEPTABILITY RESULTS

[illegible]	TOUCHDOWN CRITERIA									COMMENTS
	x_{TD}	$\dot{h}_{TD}$	θ_{TD}	U_{TD}	C_L	Y_{TD}	$\dot{Y}_{TD}$	β_{TD}	ϕ_{TD}	
B1					N/A					
B2										
B3										
B4										
B5										
B6										
B7				x						
B8	x			x						LONG, >1.3 U_{STALL}
B9		x	x	x						BOUNCE, AUTOTHROTTLE PROBLEM
B10				x						<1.0 U_{STALL}
B11										
B12				x						
D2							x			
D3	x	x	x							CRASH SHORT OF RW
D4	x	x	x	x					x	CRASH SHORT OF RW, STALL
D10	x	x	x	x			x		x	CRASH SHORT OF RW
D11										
D12	x			x						LONG, >1.3 U_{STALL}
D13				x					x	>1.3 U_{STALL}, EXCESSIVE ROLLING
D14	x			x						LONG, >1.3 U_{STALL}
D15					N/A					

x - DENOTES UNACCEPTABLE PERFORMANCE

N/A - DENOTES DATA NOT AVAILABLE

120 KT. CASE

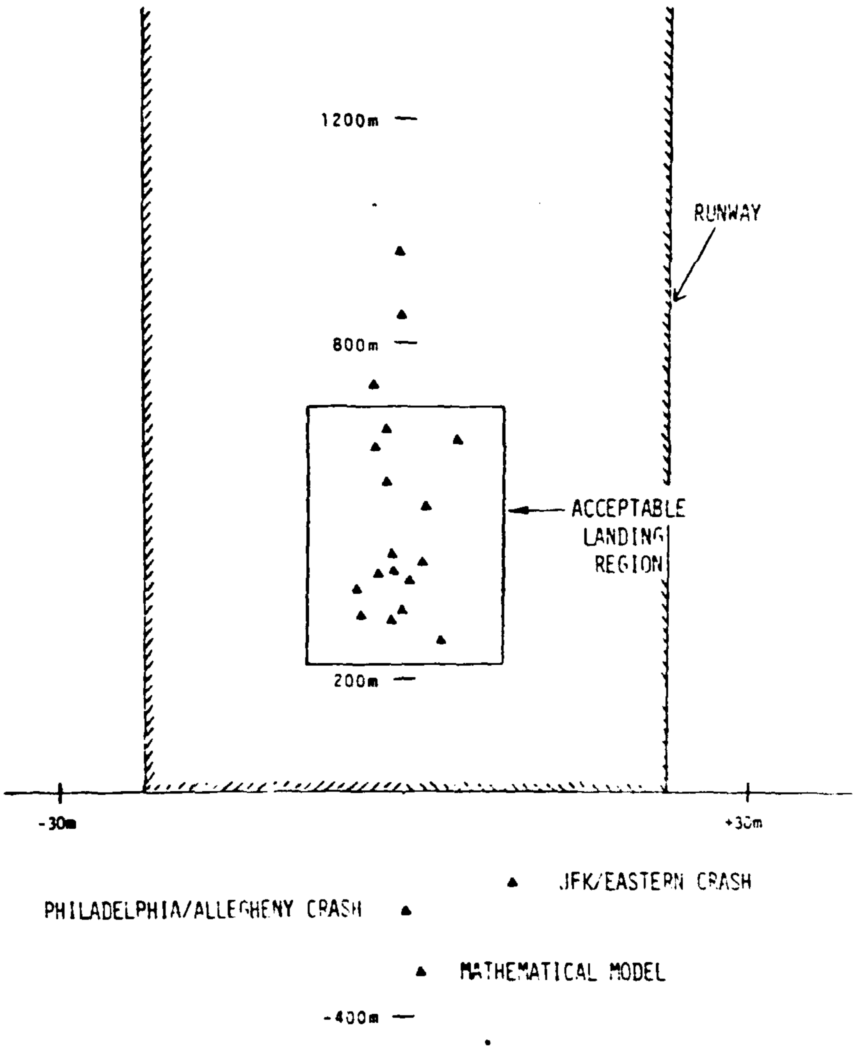


Figure 4.- Touchdown footprint for autolands vs. all profiles (IAS-120 kts).

TABLE 5.- TOUCHDOWN RESULTS FOR PILOTED RUNS

Profile Label	Touchdown Criteria								
	x_{TD}	h_{TD}	θ_{TD}	u_{TD}	C_L	γ_{TD}	$\dot{\gamma}_{TD}$	β_{TD}	ϕ_{TD}
D1	2	1		3		1,2,3			
D2	3	1,3				2			
D3			2	1,2		1			
D4	1,2,3	1,2,3	3	3		1			
D5			2	1	2				
D6	3			1		1			
D7	3			3		1,2			
D8		3	2	1,2,3		1			
D9	1	1[a]				1,2			
D10	1,2[b]	1	2	1,2,3		2			

a - *Touchdown hard enough to cause structural damage*
b - Crash short of runway
1 - Pilot number 1, unacceptable performance
2 - Pilot number 2, unacceptable performance
3 - Pilot number 3, unacceptable performance

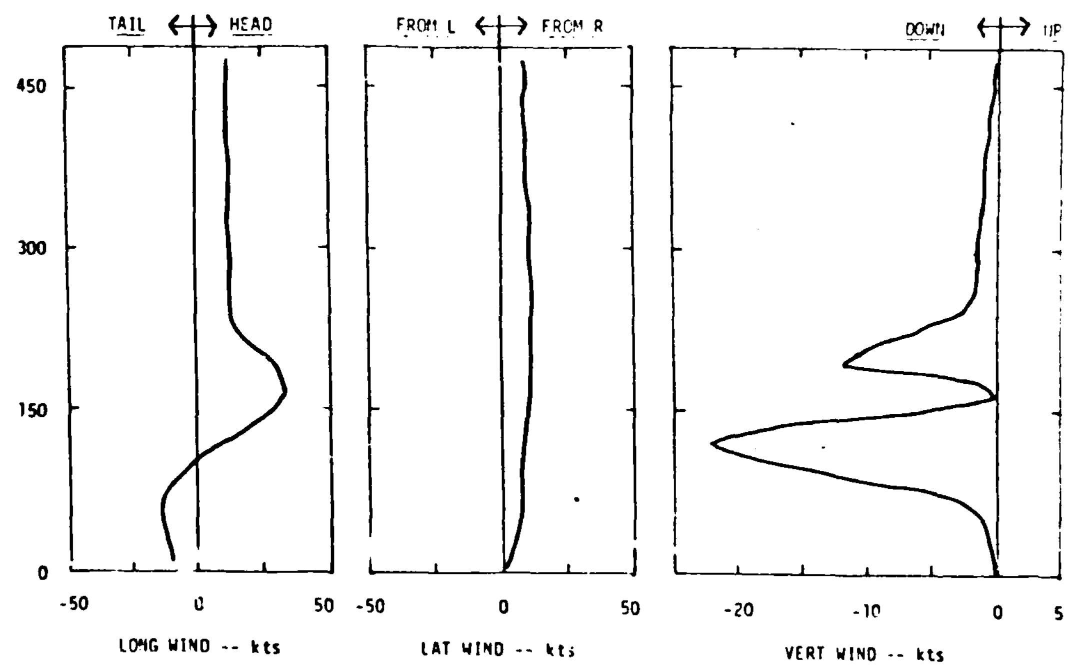


Figure 1.- Mean winds for profile D10, thunderstorm, similar to Kennedy/Eastern accident.

CONCLUSIONS

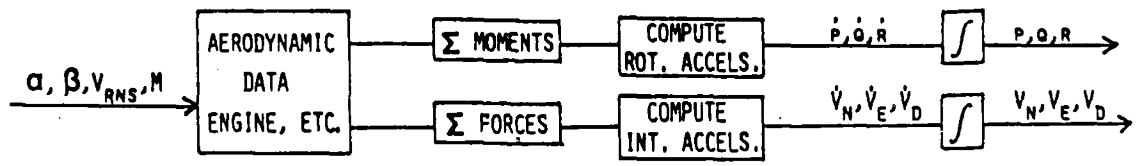
- CRASHES WILL OCCUR WITH PRESENT SYSTEM
- PILOTS COMMENTED THEY HAD NOT ENCOUNTERED SHEARS OF THESE MAGNITUDES IN ACTUAL FLIGHT
- MAGNITUDES OF TURBULENCE WERE SO GREAT THAT THEY WOULD HAVE INITIATED "GO AROUND" PRIOR TO ANY SHEAR PENETRATION
- RESPONSE OF THE AIRCRAFT TO TURBULENCE SEEMED UNREALISTIC. THIS COULD BE TO:
  - -- INCREASED VISUAL RESOLUTION OF ELECTRONIC DISPLAYS
  - -- LARGE MAGNITUDES OF TURBULENCE COMPONENTS
  - -- IMPROPER TURBULENCE MODEL OR IMPLEMENTATION

CONCERNS

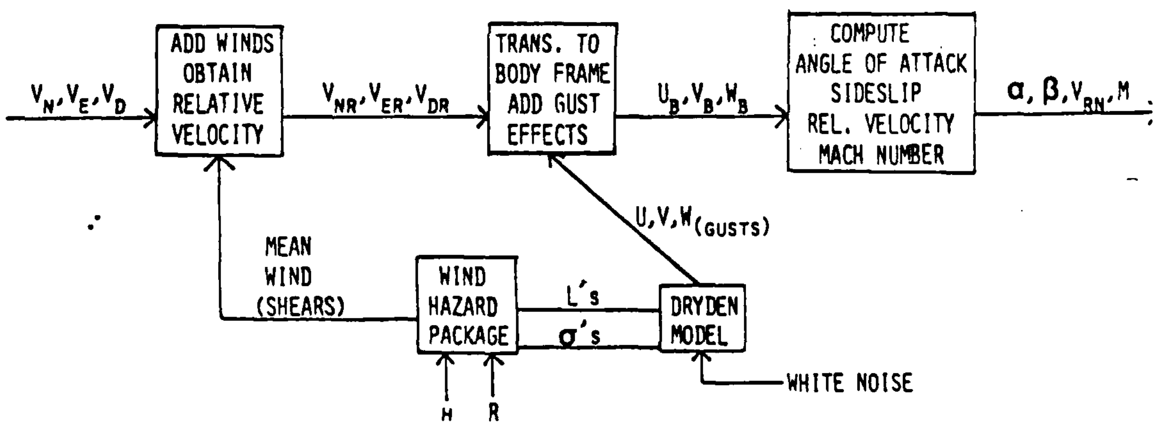
- VALIDITY OF IMPLEMENTATION AND MODELING OF ATMOSPHERICS
- PROBLEMS WITH STANDARDIZATION BASED ON DISCUSSIONS WITH SRI, FAA, UAL, BOEING, DOUGLAS, SINGER-LINK AND SAFEFLIGHT
    - INCONSISTENCIES WITH PLACEMENT OF WINDSHEAR/TURBULENCE INTO EQUATIONS OF MOTION
    - CHARACTER AND IMPLEMENTATION OF TURBULENCE MODELS
    - INCLUSION OF SPAN AND AREA AVERAGING FILTERS (FAA ADVISORY CIRCULAR 20-57A)
    - UNSTEADY LIFT EFFECTS AS CONTRASTED TO LUMPED-PARAMETER (QUASI-STEADY) AERO MODELS

RECOMMENDATIONS

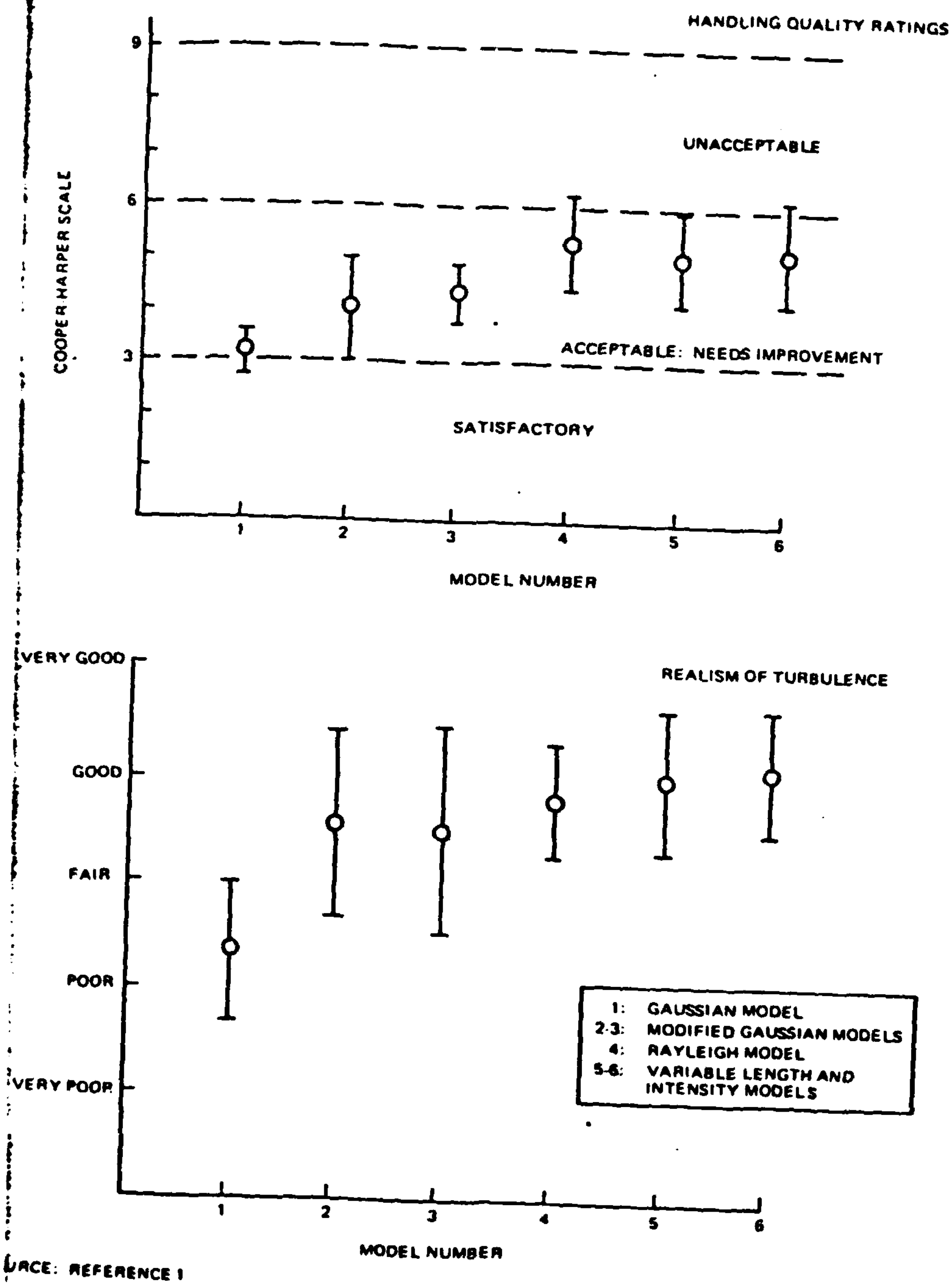
- SIMULATION COMMUNITY DRIVE TOWARD STANDARDS AS REGARDS
  - WIND HAZARDS DATA BASE
  - MODELS
  - IMPLEMENTATION TECHNIQUES
- LaRC SEVERE STORMS ~~STOMRS~~ PROGRAM
  - NEW DATA BASE
  - IMPROVED MODELING OPPORTUNITIES
- FAA ROLE



α, β, V_RNS, M
AERODYNAMIC DATA ENGINE, ETC.
Σ MOMENTS
Σ FORCES
COMPUTE ROT. ACCELS.
COMPUTE INT. ACCELS.
Ṗ, Q̇, Ṙ
P, Q, R
V̇_N, V̇_E, V̇_D
V_N, V_E, V_D



V_N, V_E, V_D
ADD WINDS OBTAIN RELATIVE VELOCITY
V_NR, V_ER, V_DR
TRANS. TO BODY FRAME ADD GUST EFFECTS
U_B, V_B, W_B
COMPUTE ANGLE OF ATTACK SIDESLIP REL. VELOCITY MACH NUMBER
α, β, V_RN, M
U, V, W (GUSTS)
MEAN WIND (SHEARS)
WIND HAZARD PACKAGE
L's
σ's
DRYDEN MODEL
WHITE NOISE
H
R



URCE: REFERENCE 1

FIGURE 5. PILOT OPINION RATINGS

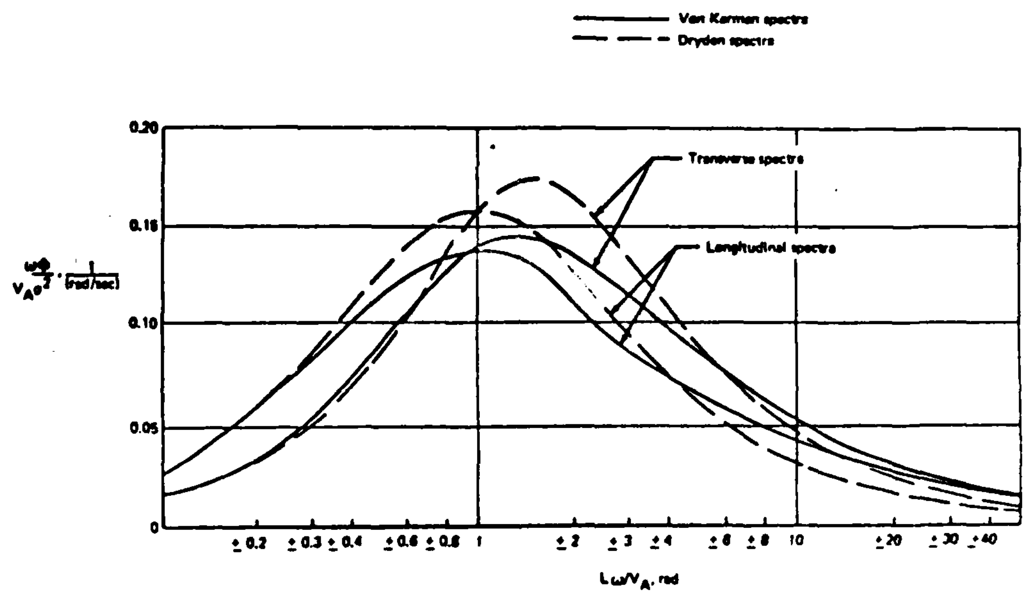


FIGURE 19 — COMPARISON: DRYDEN AND VON KARMAN VARIANCE DENSITY

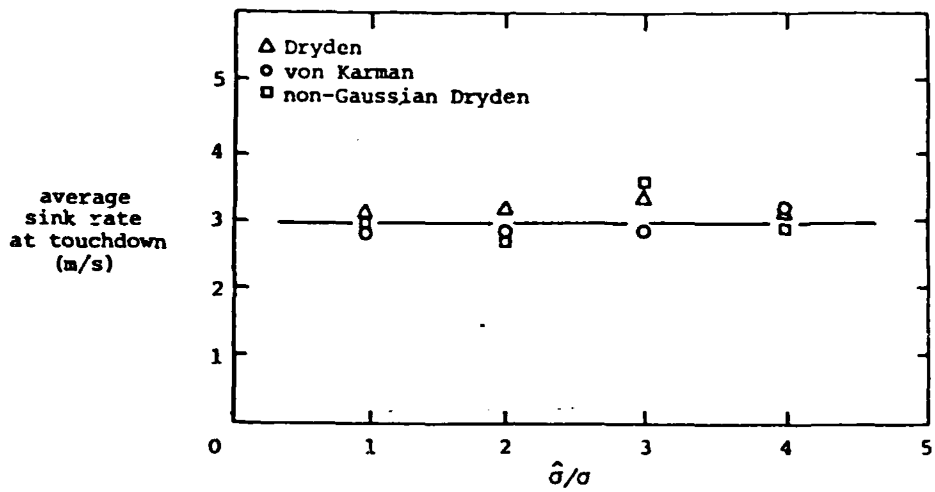


Figure 5-7. The average sink rate for different turbulence models ($u_* = 0.5$, $z_o = 0.1$).

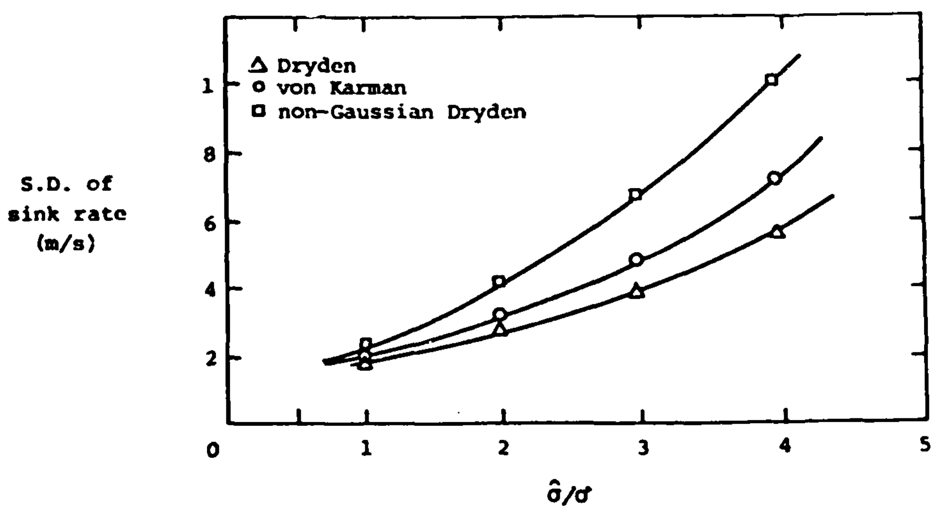


Figure 5-8. The standard deviation of sink rate for different turbulence models ($u_* = 0.5$, $z_o = 0.1$).

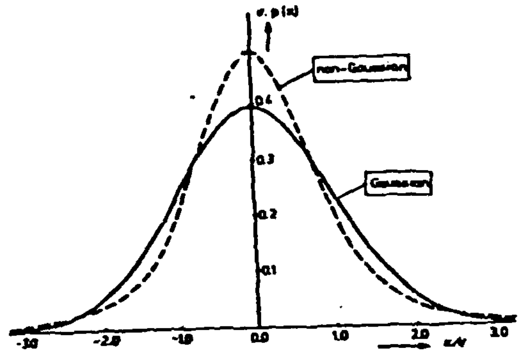


Fig. 1. The Gaussian - and a possible non-Gaussian distribution function.

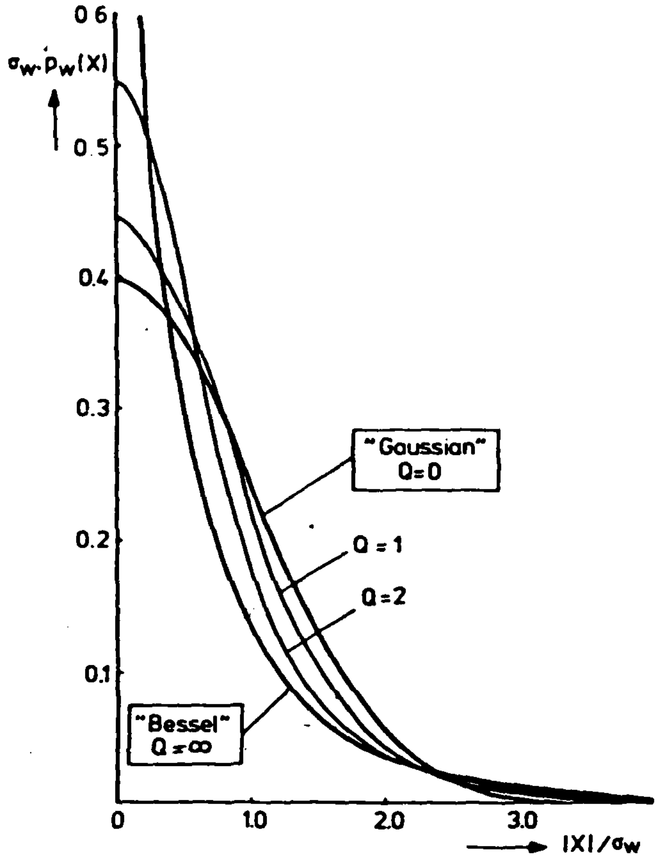


Fig. 4. Normalized probability density functions of w(t) for various values of Q.

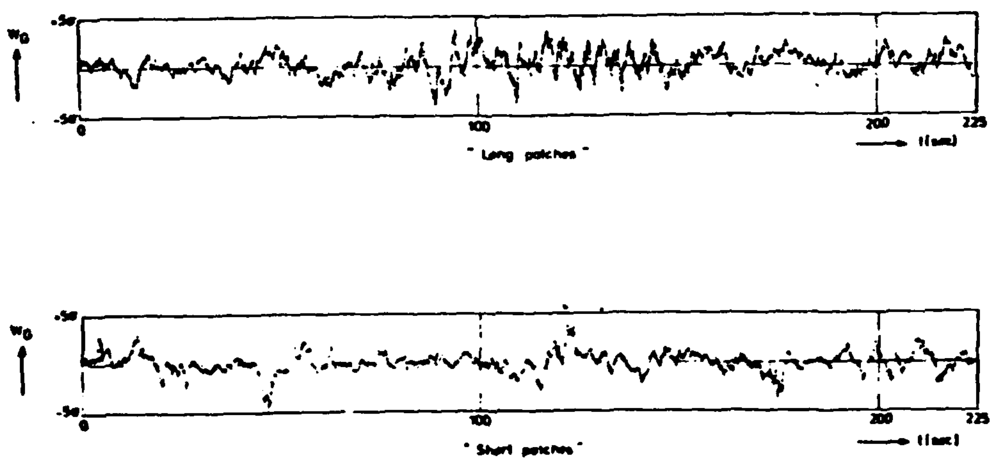


Fig. 5. Two non-gaussian turbulence records with the same fourth order moment setting but different "average patchlength".

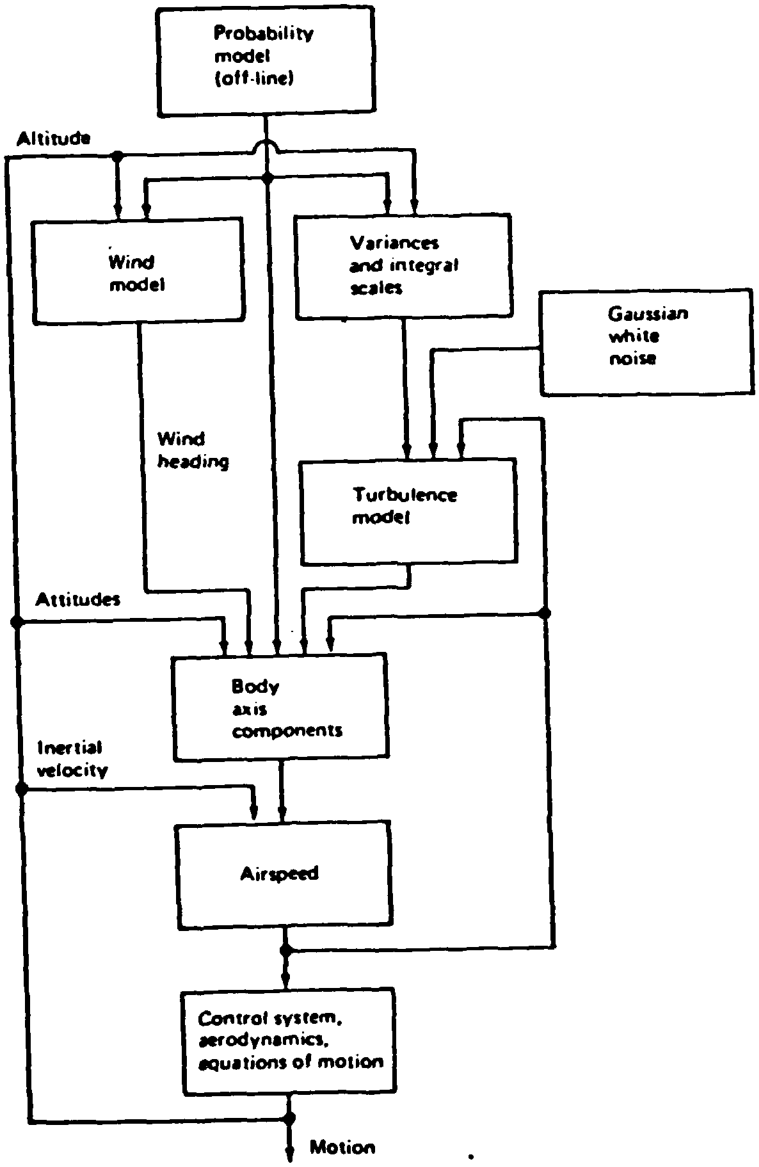


FIGURE 30 —COMPUTATION FLOW DIAGRAM

"THE ANSWER MY FRIEND IS BLOWING IN THE WIND . . ."

BOB DYLAN

CLEAR AIR TURBULENCE

M. L. Kaplan (SASC)

OVERVIEW

1) MESOSCALE ATMOSPHERIC SIMULATION SYSTEM (M.A.S.S.)

2) DC-10 ACCIDENT/APRIL 3, 1981 WEATHER SITUATION

3) MODEL SIMULATION RESULTS

4) M.A.S.S. POTENTIAL UTILITY FOR C.A.T., WIND SHEAR, AND TURBULENCE HAZARDS FORECASTING

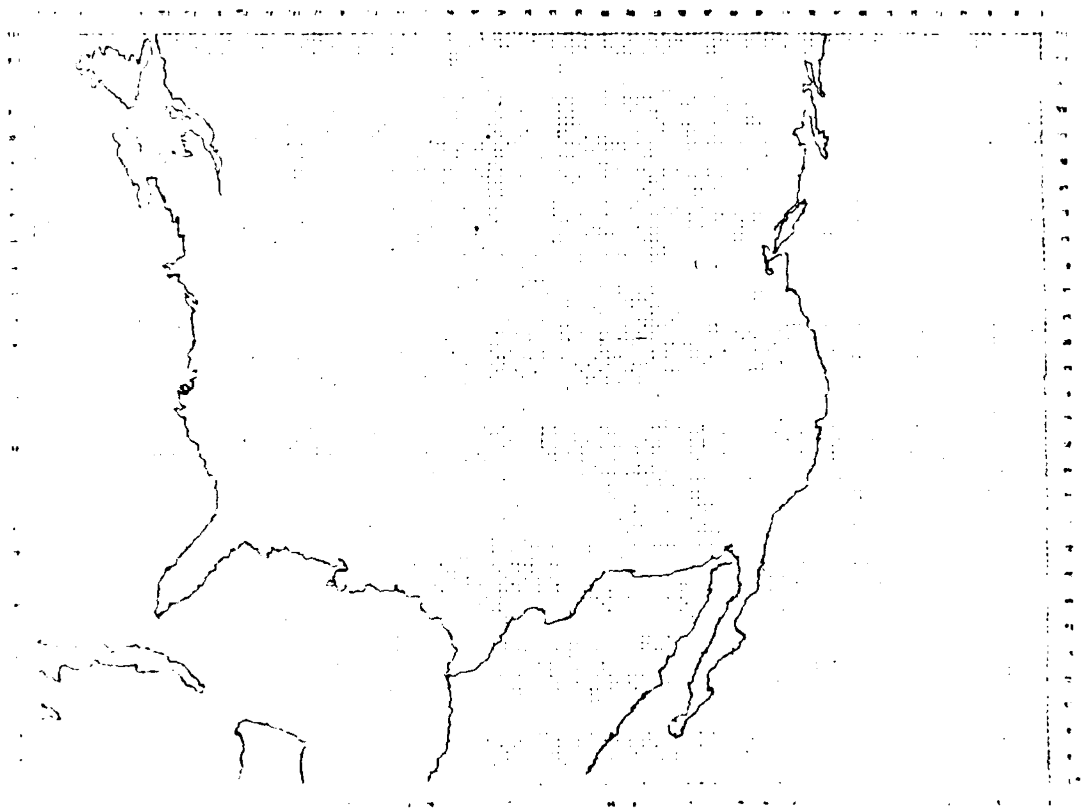
16d

1) MESOSCALE ATMOSPHERIC SIMULATION SYSTEM
(M.A.S.S.)

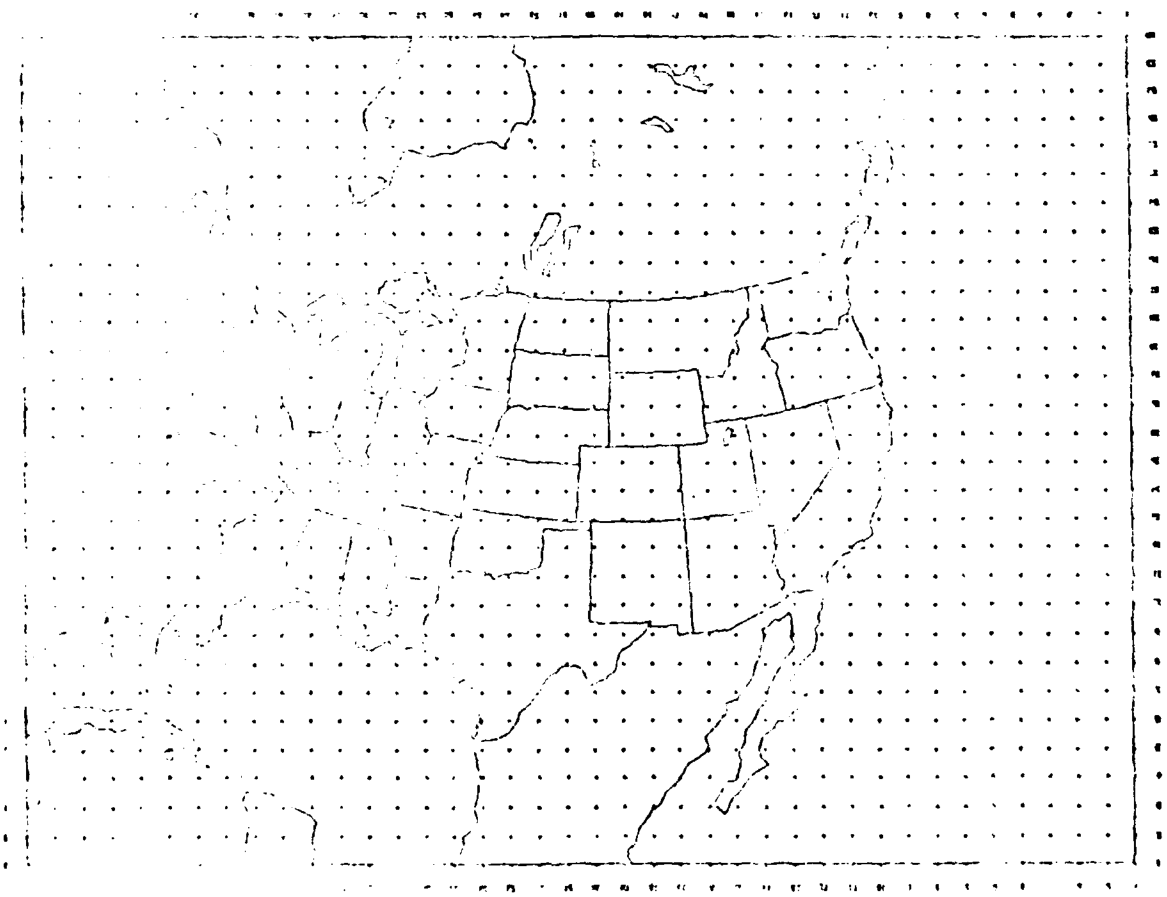
SYSTEMS AND APPLIED SCIENCES CORPORATION

MESOSCALE ATMOSPHERIC SIMULATION SYSTEM

* 48 KM MESOSCALE MODEL
* SIXTH ORDER SPACE DIFFERENCING
* PREDICTOR-CORRECTOR TIME MARCHING
* 14 VERTICAL LAYERS IN A SIGMA COORDINATE
* 157 X 117 HORIZONTAL MATRIX
* PBL PARAMETERIZATION BASED ON SIMILARITY THEORY
* SURFACE ENERGY BUDGET
* DRY CONVECTIVE ADJUSTMENT
* STABLE LATENT HEATING
* CUMULUS PARAMETERIZATION UNDER DEVELOPMENT
* 24 HOUR SIMULATION IN [illegible] MINUTES ON CYBER 205
* CAPABILITY OF NESTING TO 24, 12 AND 6 KM
* NON-LINEAR NORMAL MODE INITIALIZATION UNDER DEVELOPMENT



"Horizontal grid for MASS model"



"Horizontal grid used in routine operational simulation model"

M. A. S. S. APPLICATIONS

I STRATOSPHERIC-TROPOSPHERE INTERACTIONS

1) JET STREAM TRAJECTORIES FOR AVIATION AND OZONE
2) MASS BUDGET CALCULATION NEAR TROPOPAUSE
3) OZONE BALANCE NEAR TROPOPAUSE

II POLLUTANT TRANSPORT

1) BOUNDARY LAYER TRANSPORT OF CONSTITUENTS
2) MIXING DEPTH ESTIMATION FROM BOUNDARY LAYER HEIGHT SIMULATION
3) EFFECT OF POLLUTANTS ON RADIATION BALANCE

III SATELLITE DATA

1) THOMS OZONE GRADIENTS FOR MODEL INITIALIZATION AND VERIFICATION
2) VAS AND NIMBUS FOR BETTER TEMPERATURE AND MOISTURE INITIALIZATION AND VERIFICATION
3) CLOUD STEREO WINDS FOR BETTER WIND INITIALIZATION AND VERIFICATION

IV HEAVY PRECIPITATION

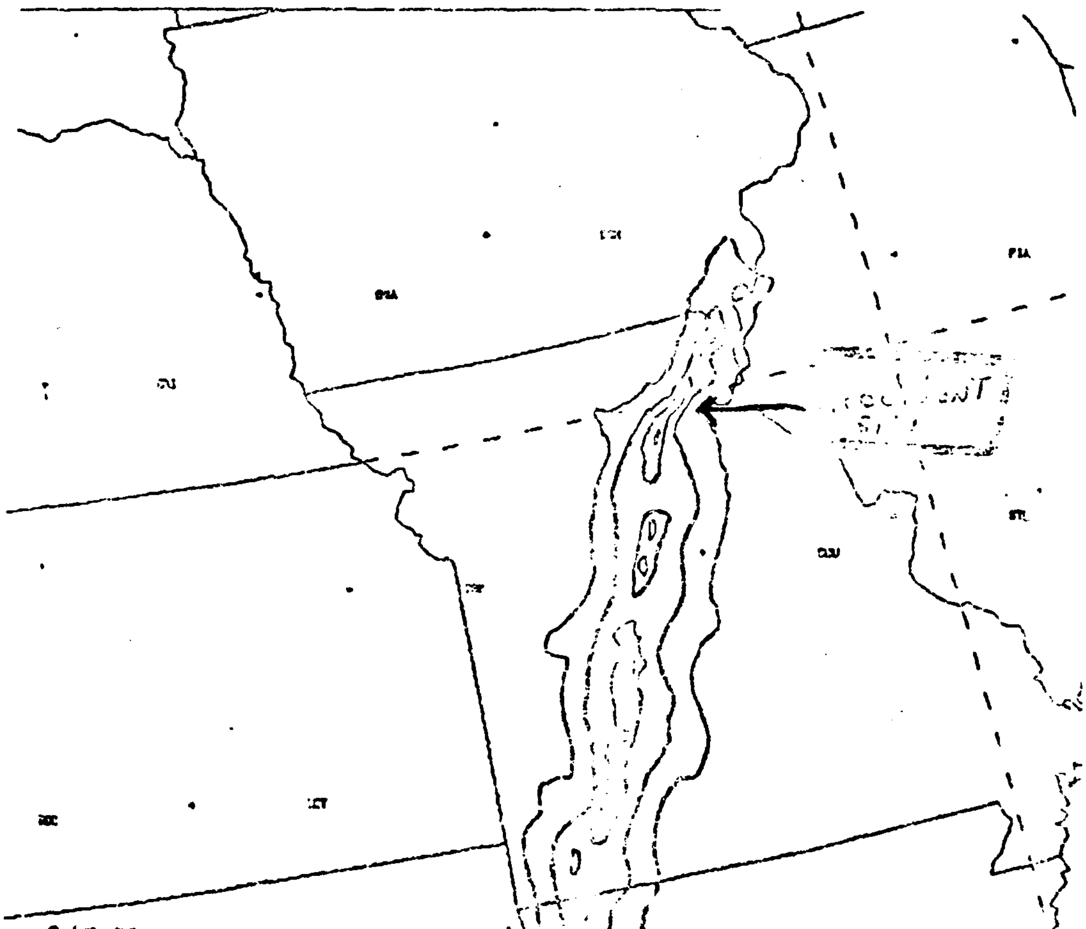
1) FLASH FLOOD/BETTER QUANTITATIVE PRECIPITATION FORECASTING
2) SHUTTLE/ACID RAIN PROBLEM
3) AIRCRAFT ICING PROBLEMS

M. A. S. S. APPLICATIONS (CONTINUED)

V SEVERE STORMS

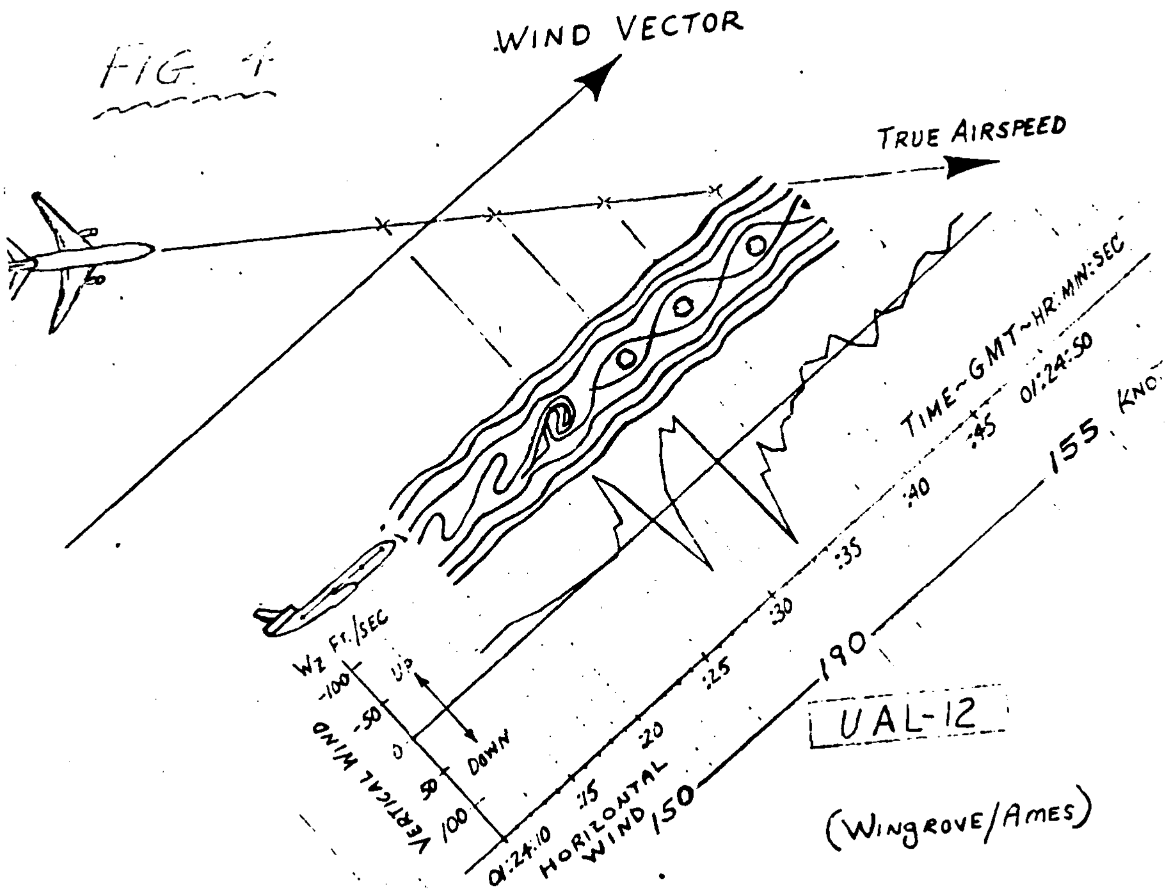
1) CYCLOGENESIS
2) SEVERE STORMS AND TORNADOES
3) SHUTTLE LIFT-OFF AND RETURN ENVIRONMENTS
4) CONVECTIVE MIXING OF OZONE OR OTHER CONSTITUENTS
5) TROPICAL EXTRATROPICAL INTERACTION PROBLEMS
6) CLEAR AIR TURBULENCE/WIND SHEAR HAZARDS

2) DC-10 ACCIDENT/APRIL 3, 1981 WEATHER SITUATION

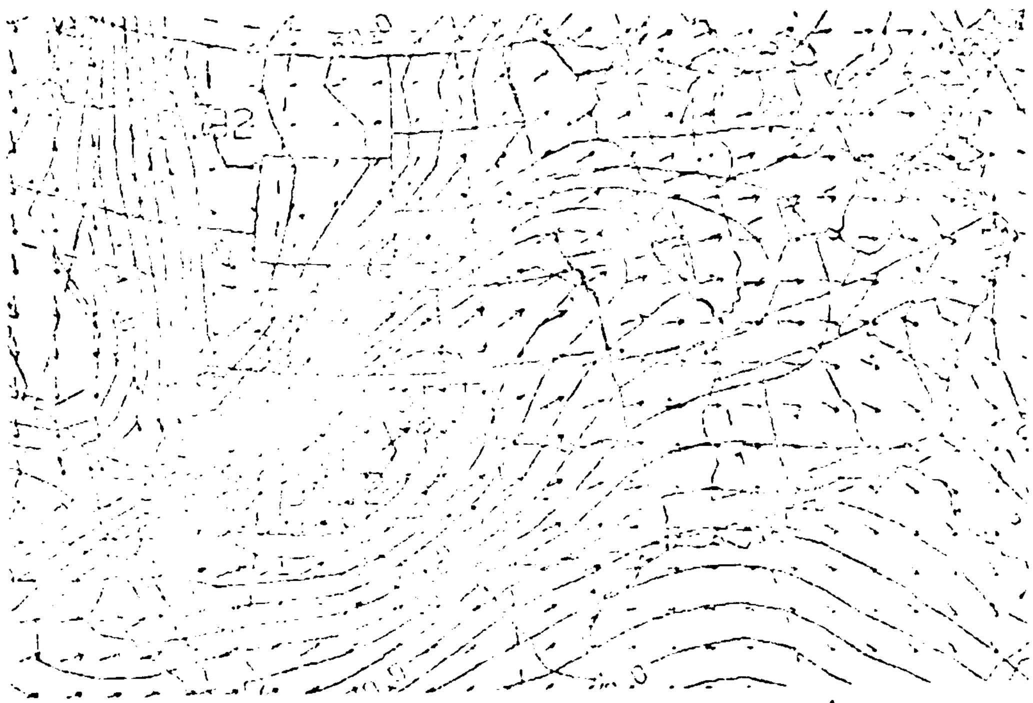


0125 GMT (ACCIDENT)

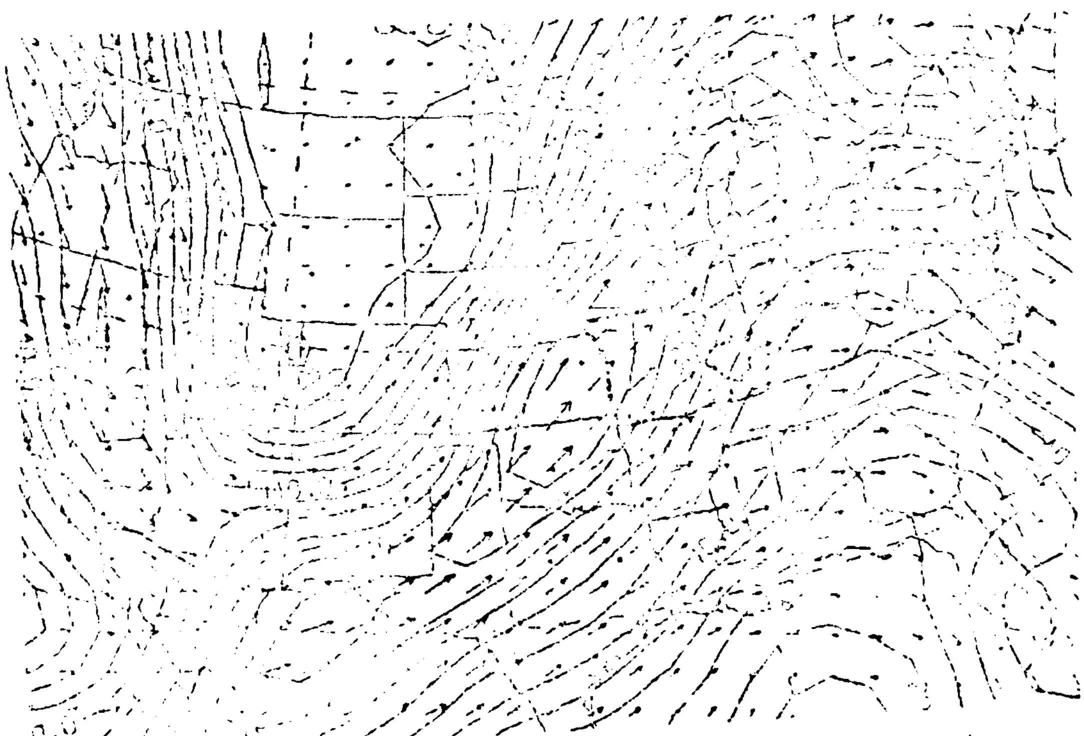
FIG. 4



(Wingrove/Ames)



∇ 250 Mb 1200 GMT 3 APRIL



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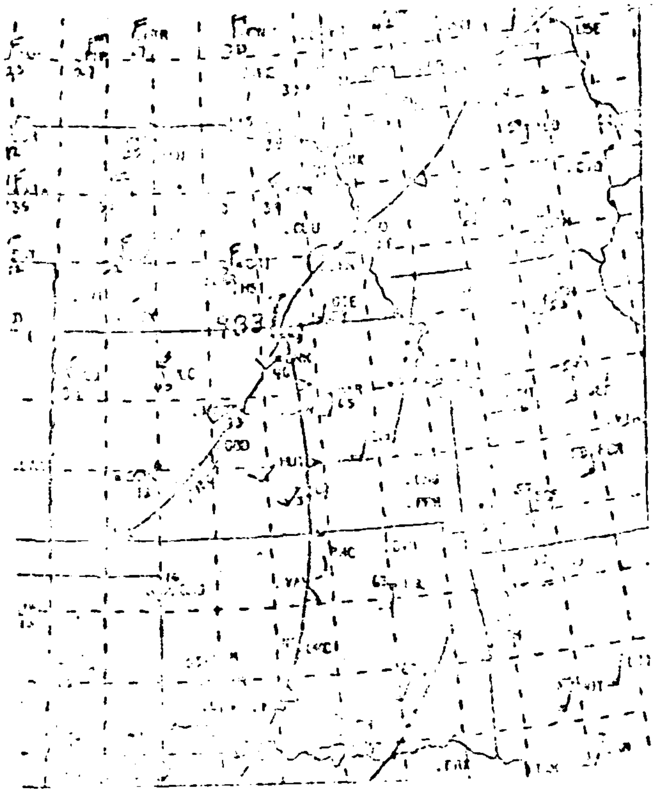

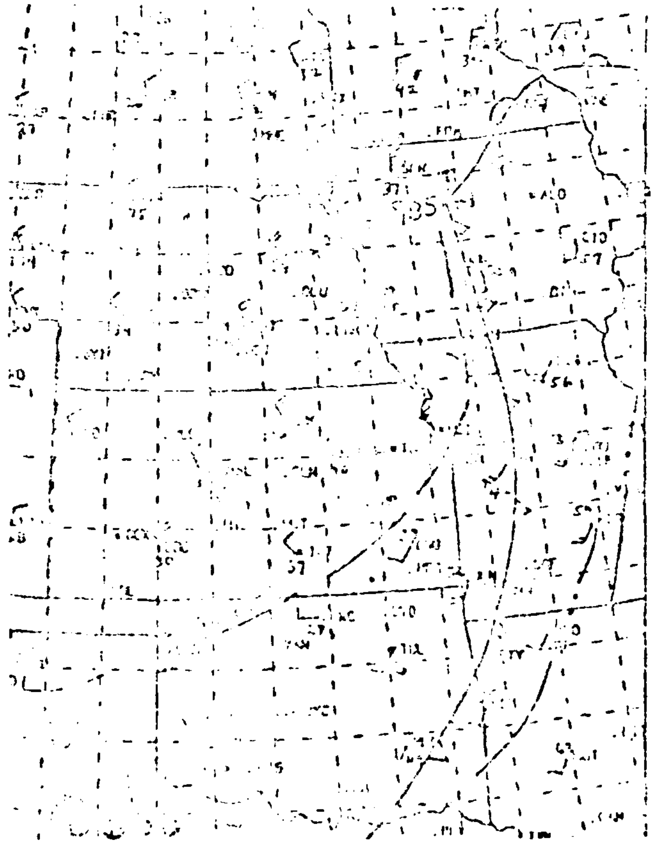

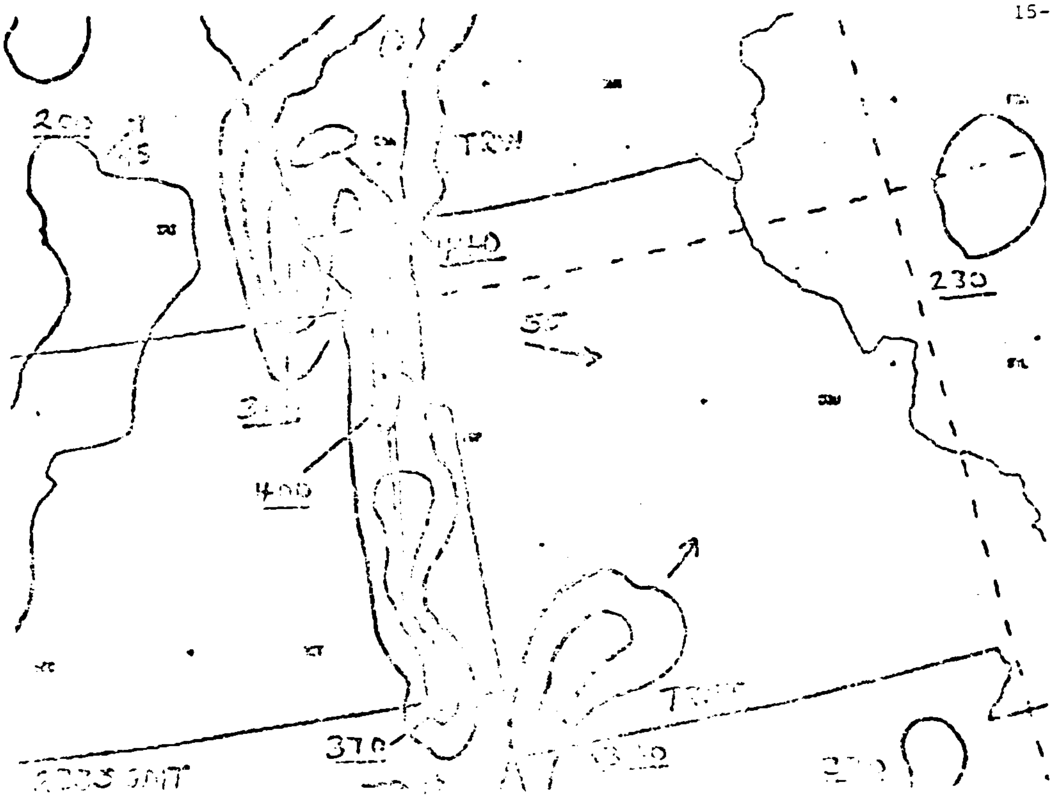
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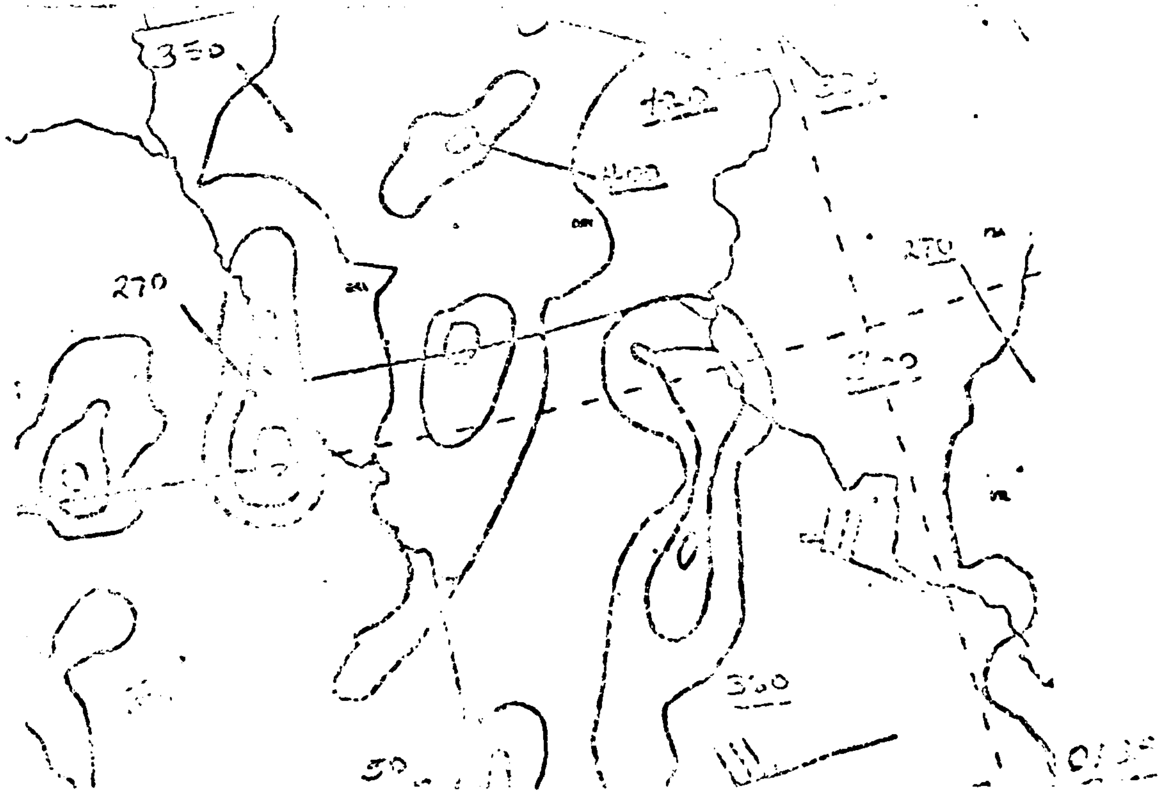
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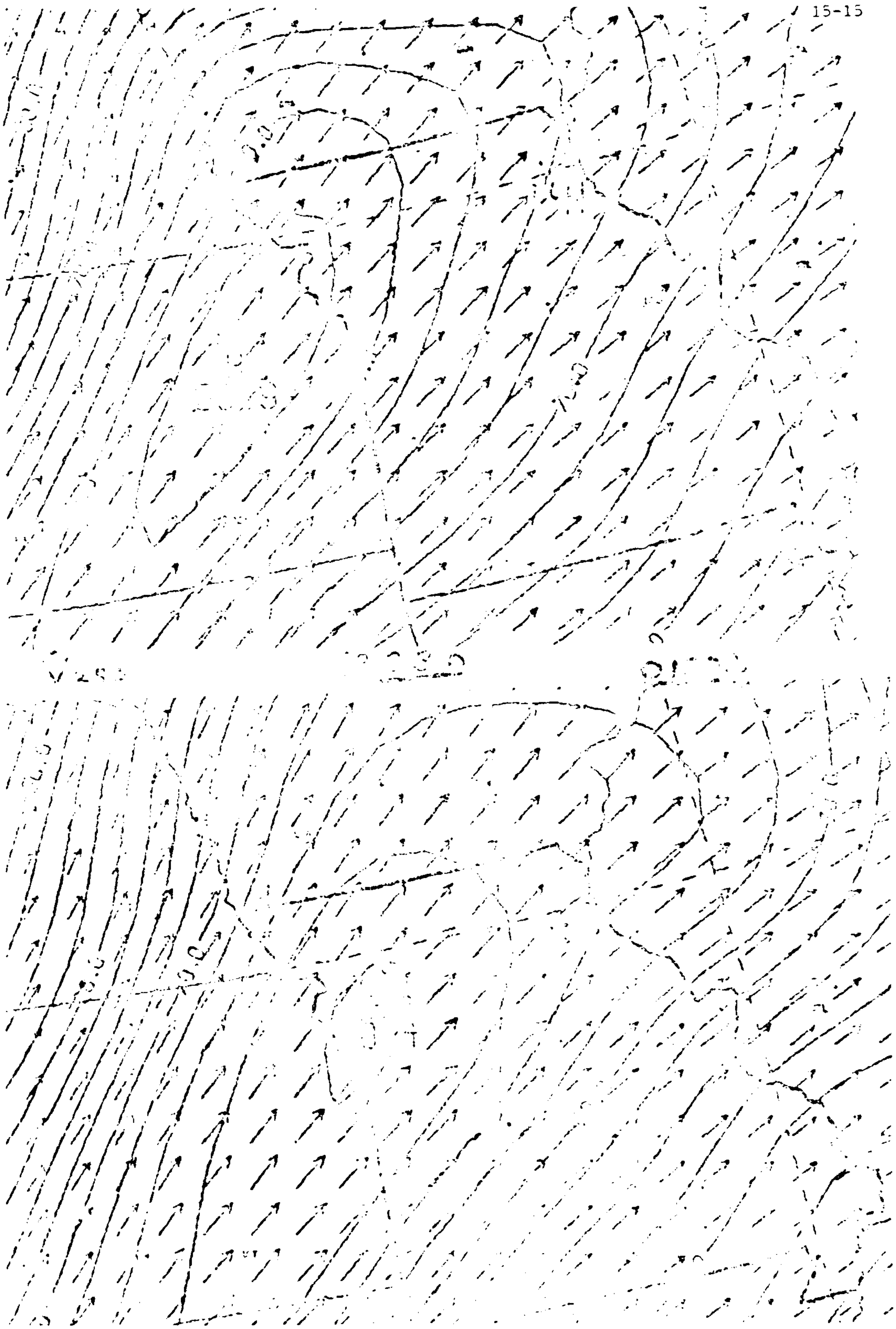
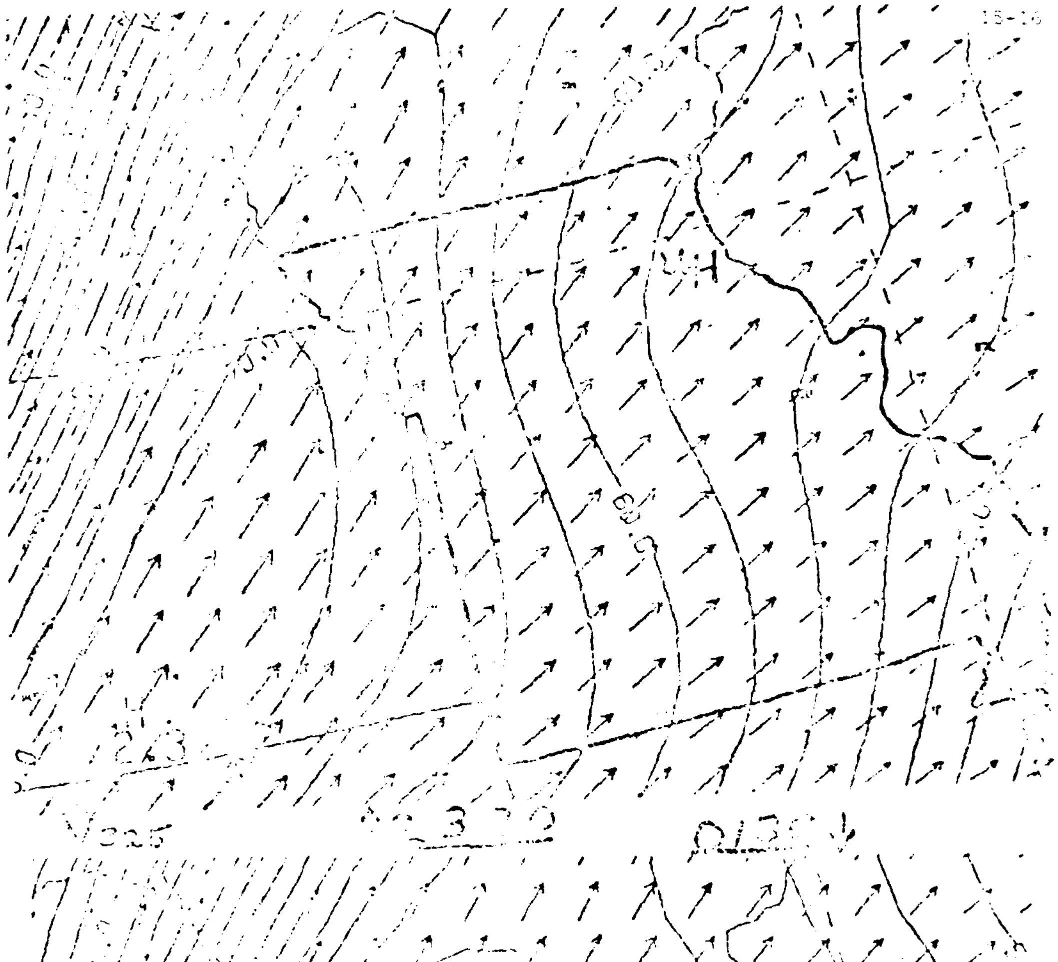
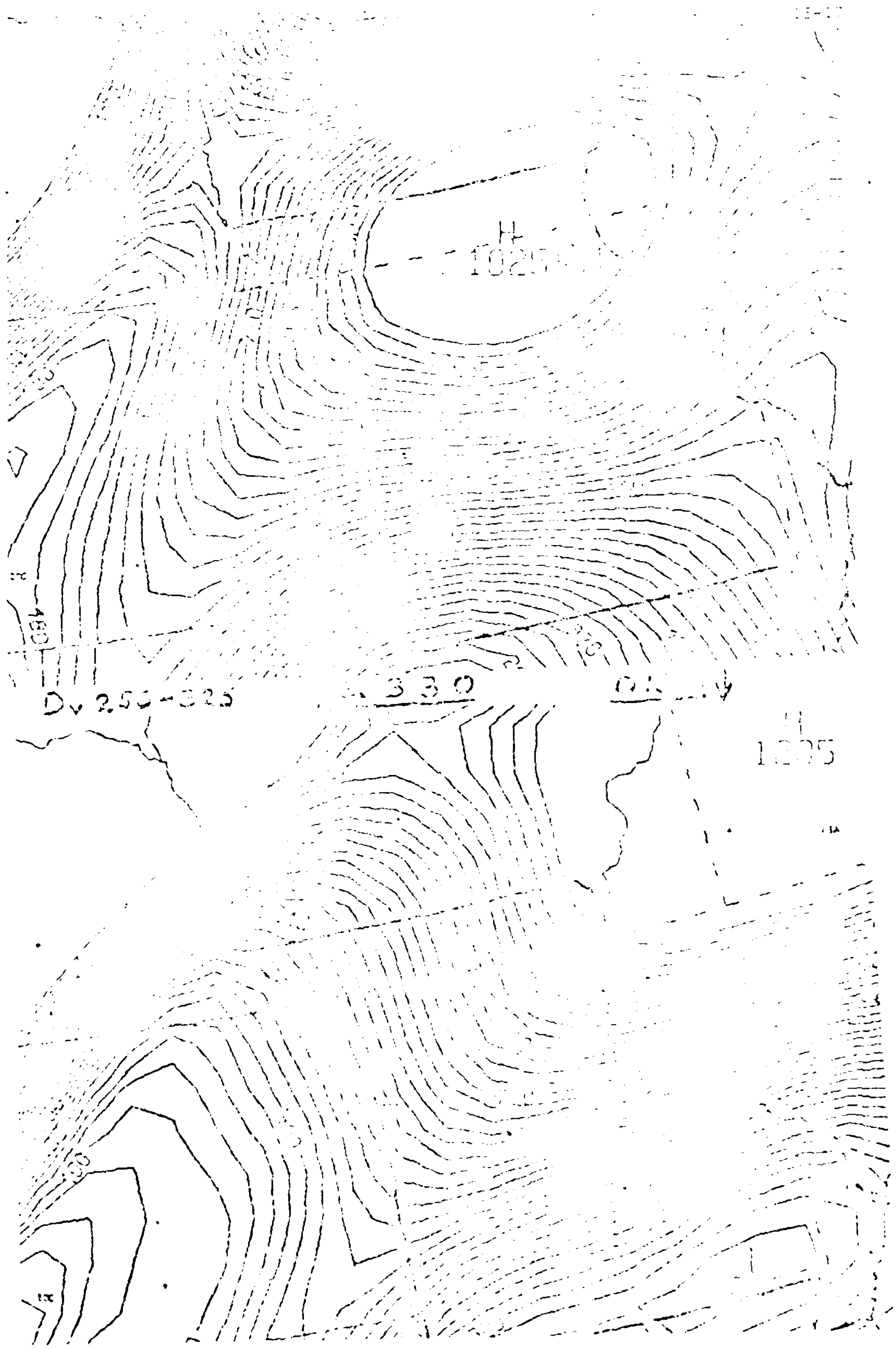
270

3) MODEL SIMULATION RESULTS



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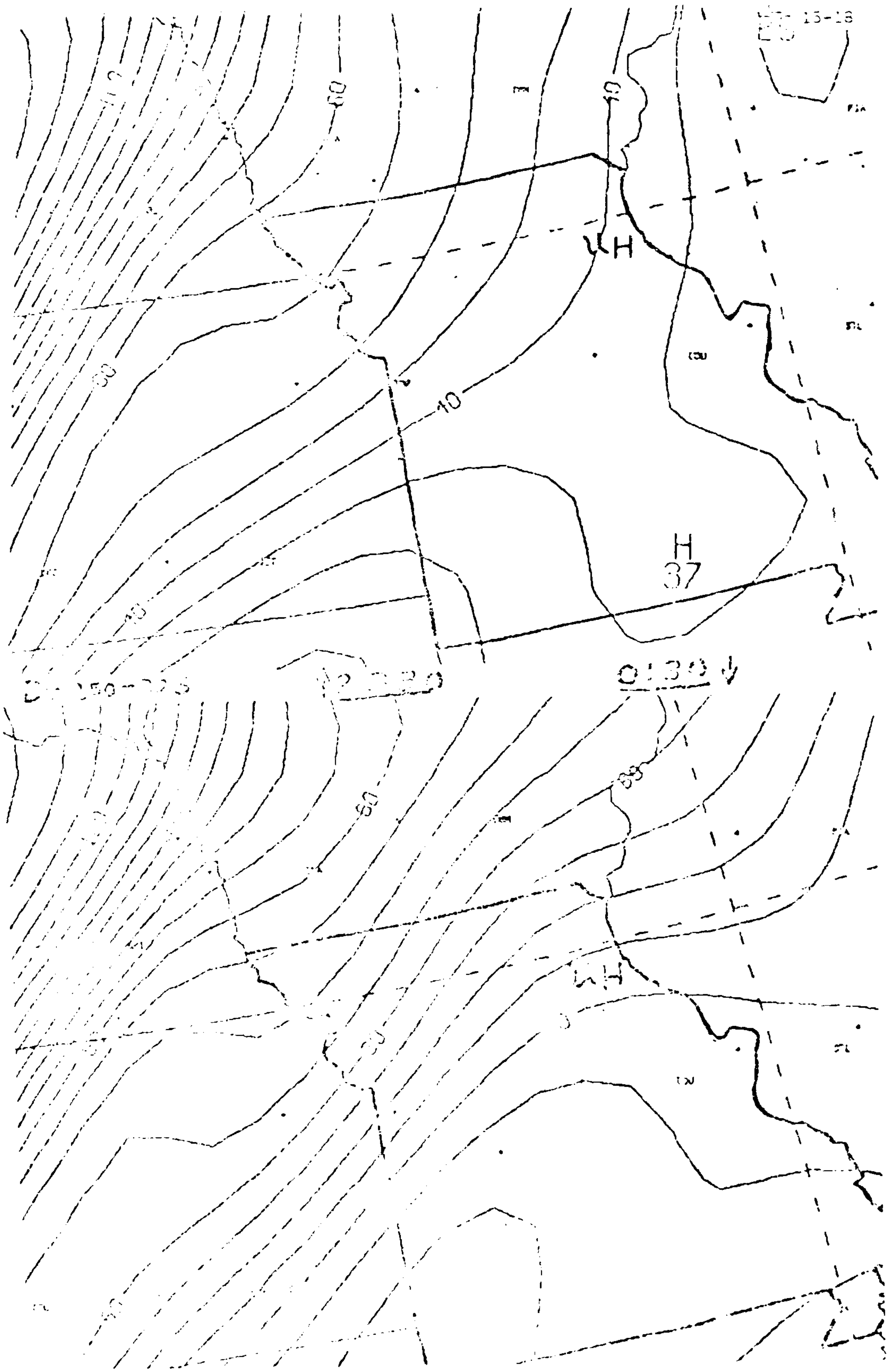
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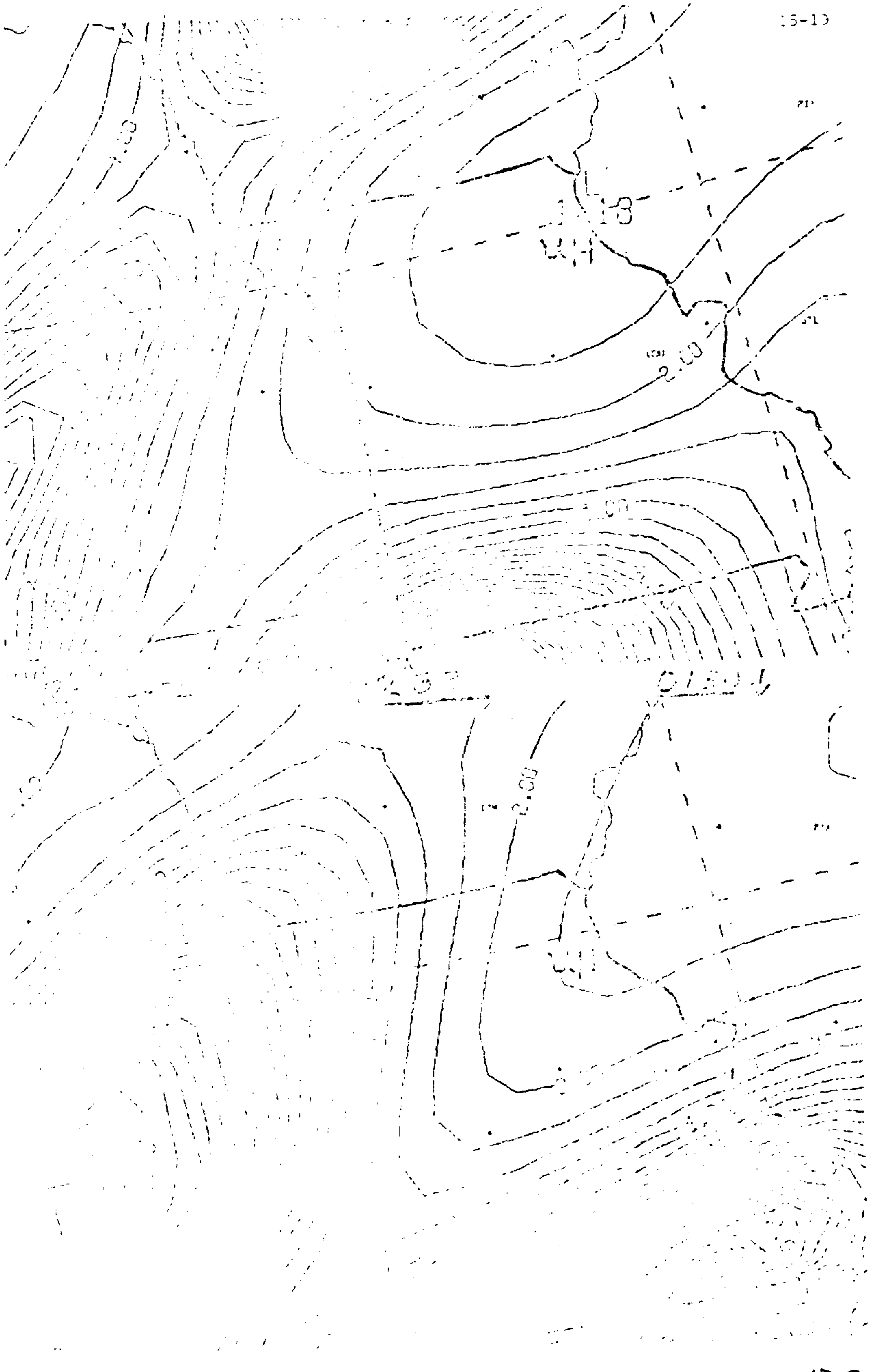
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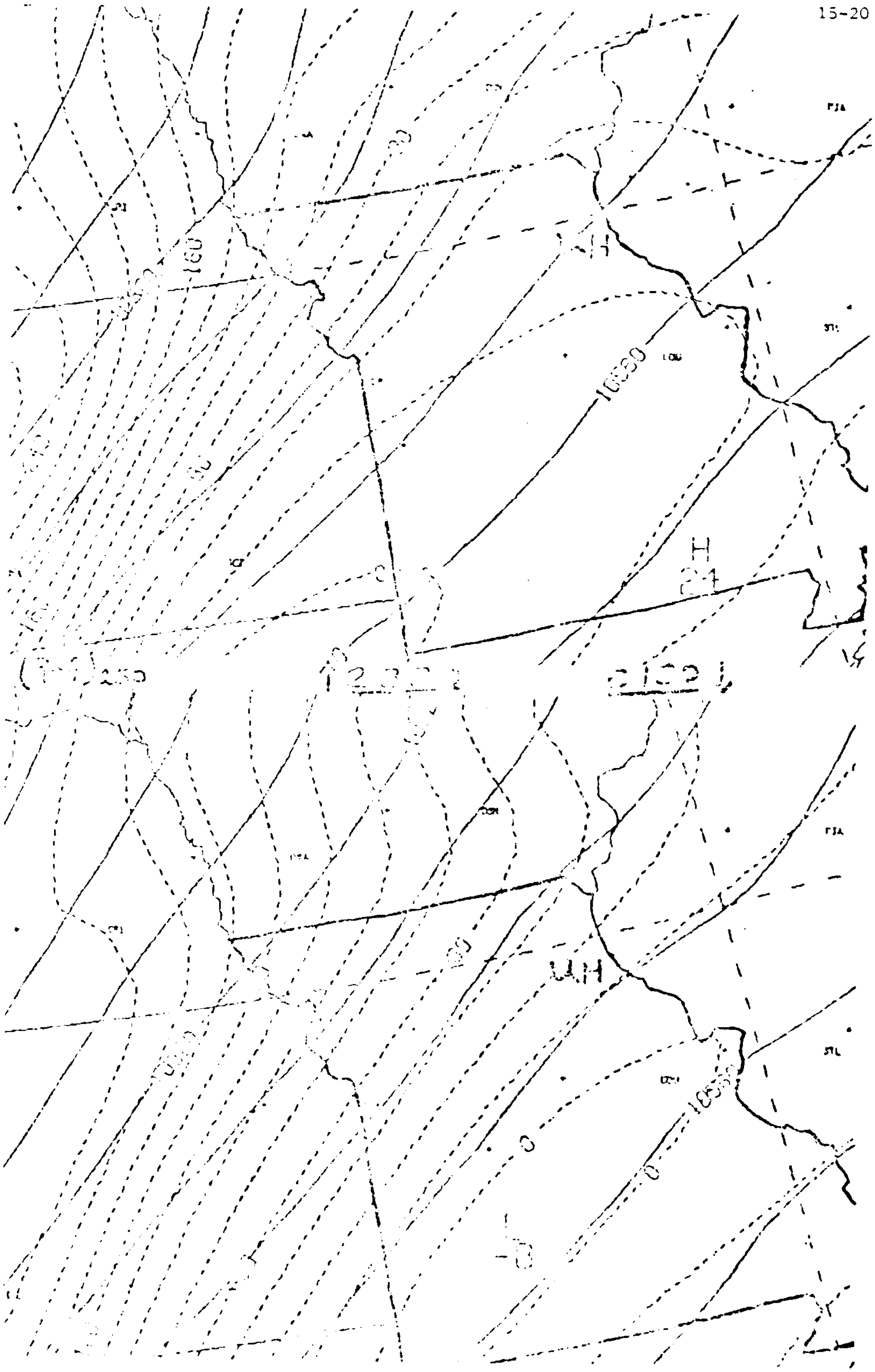

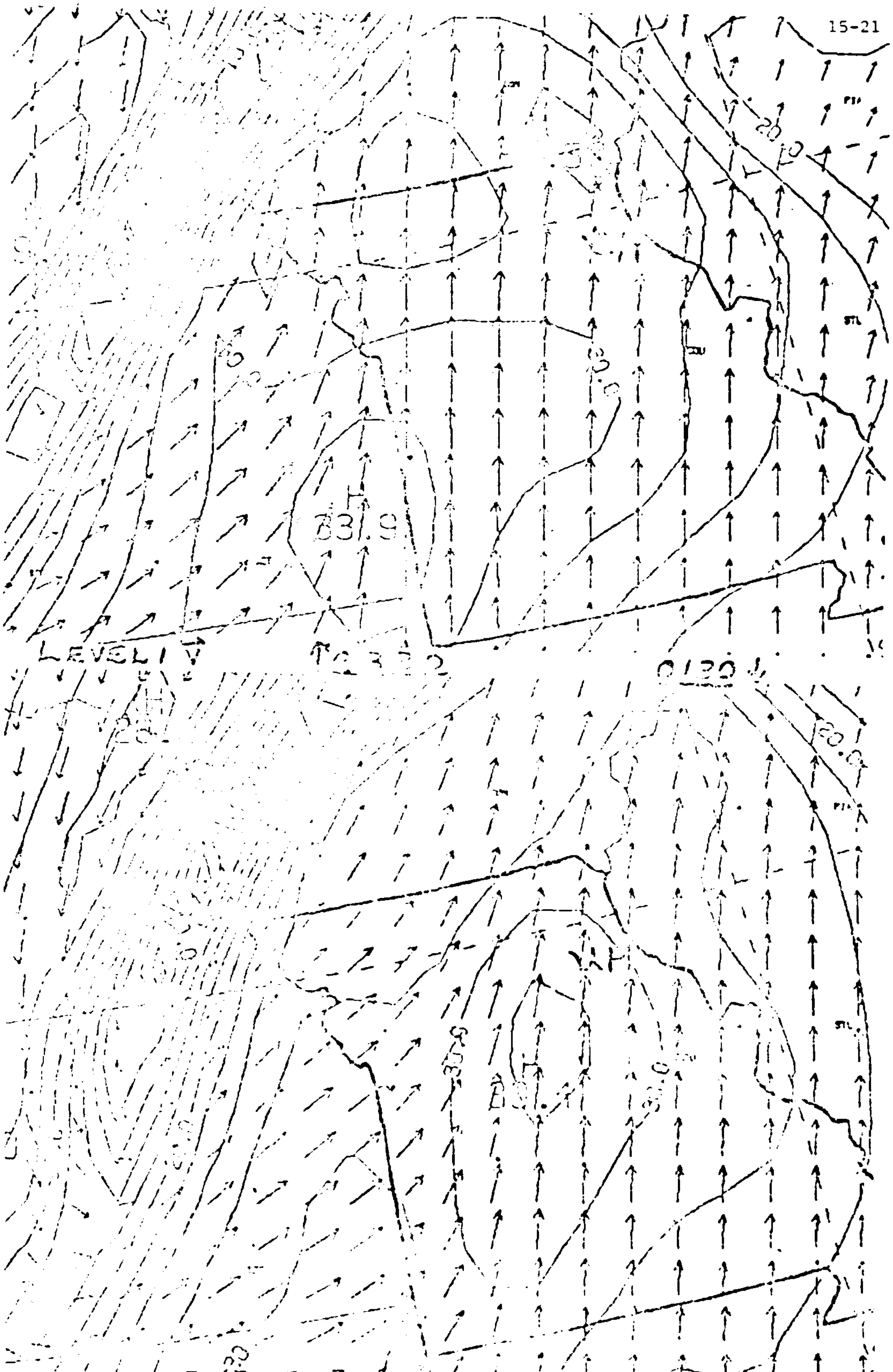
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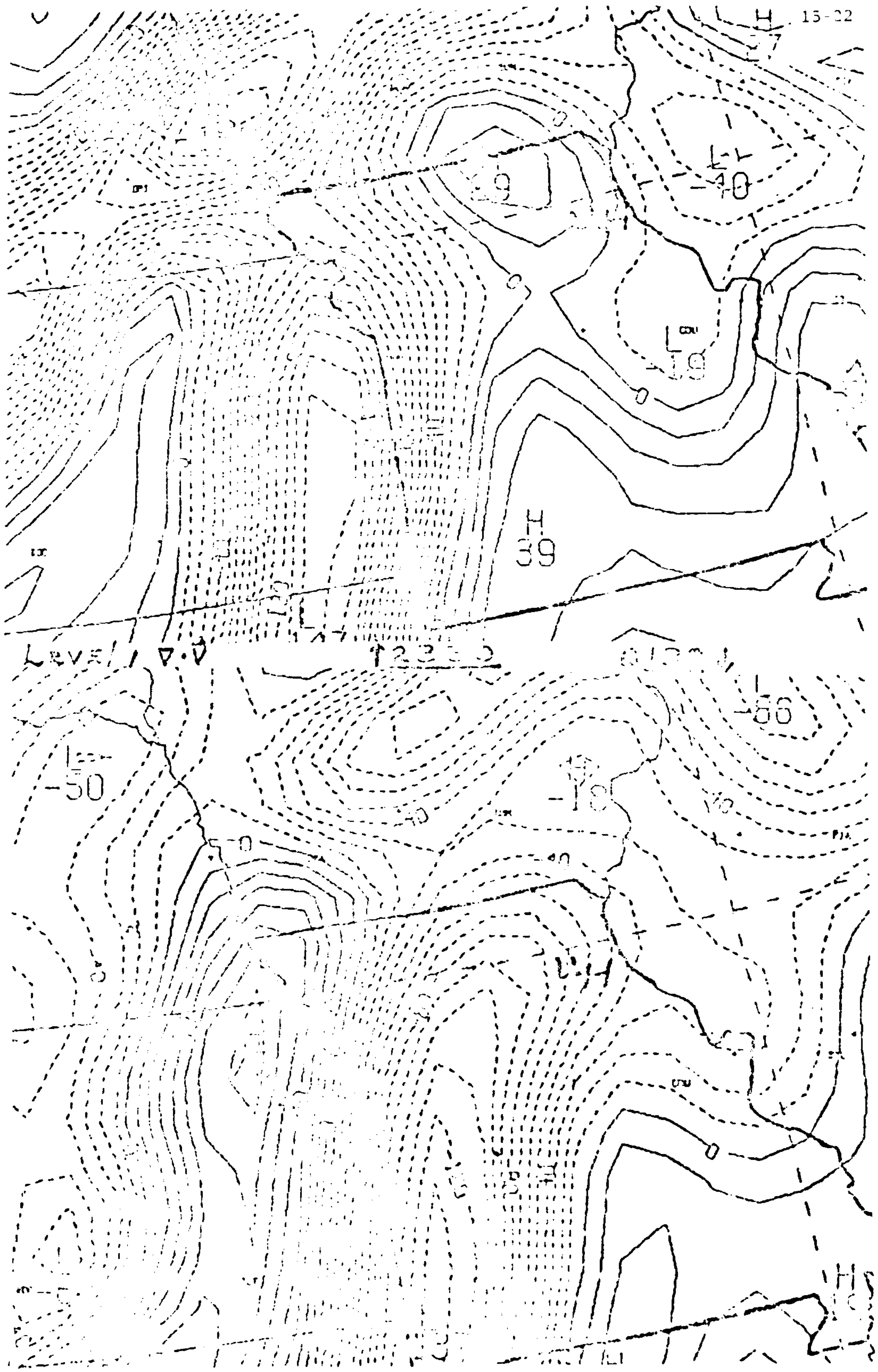

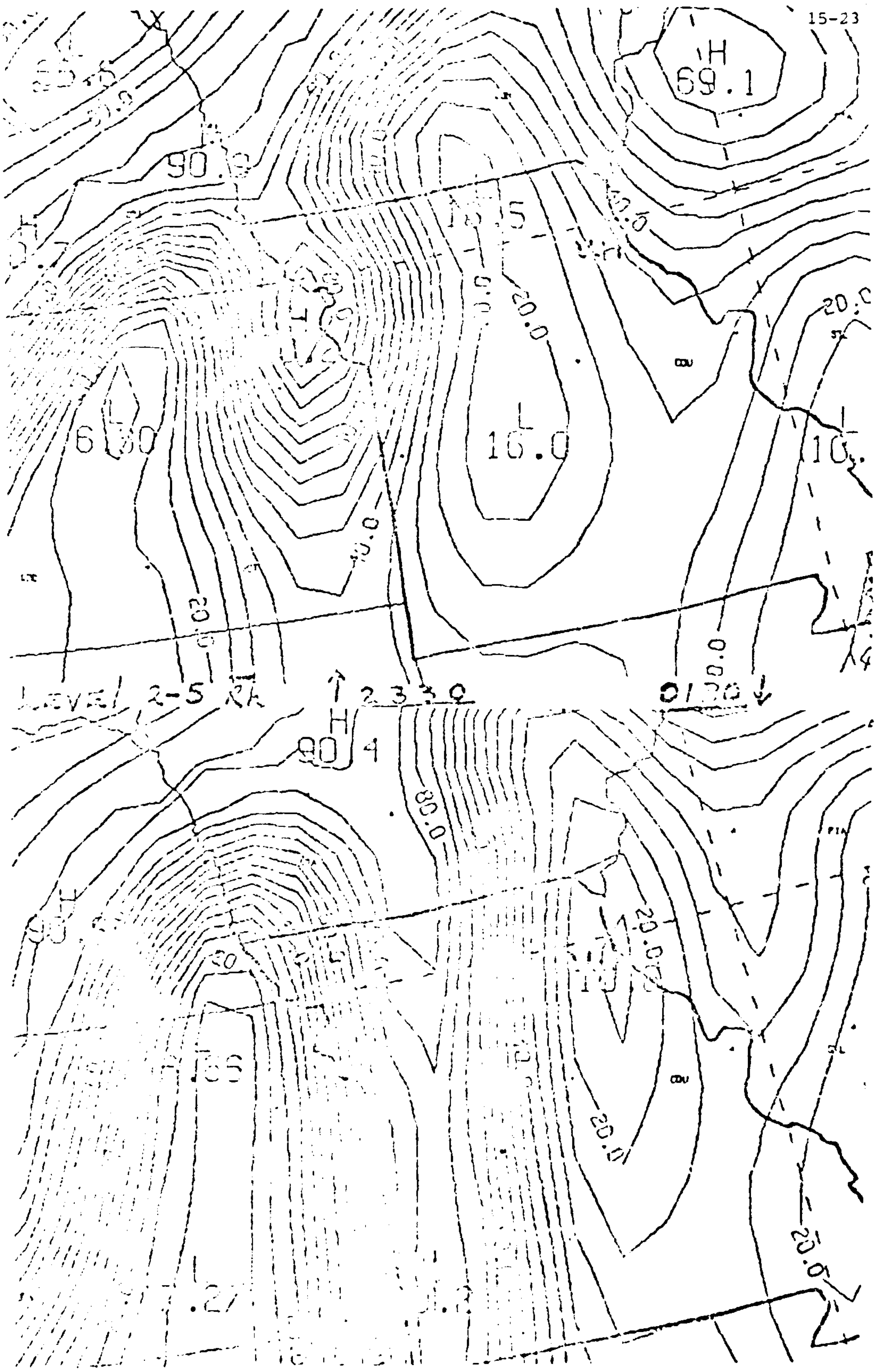
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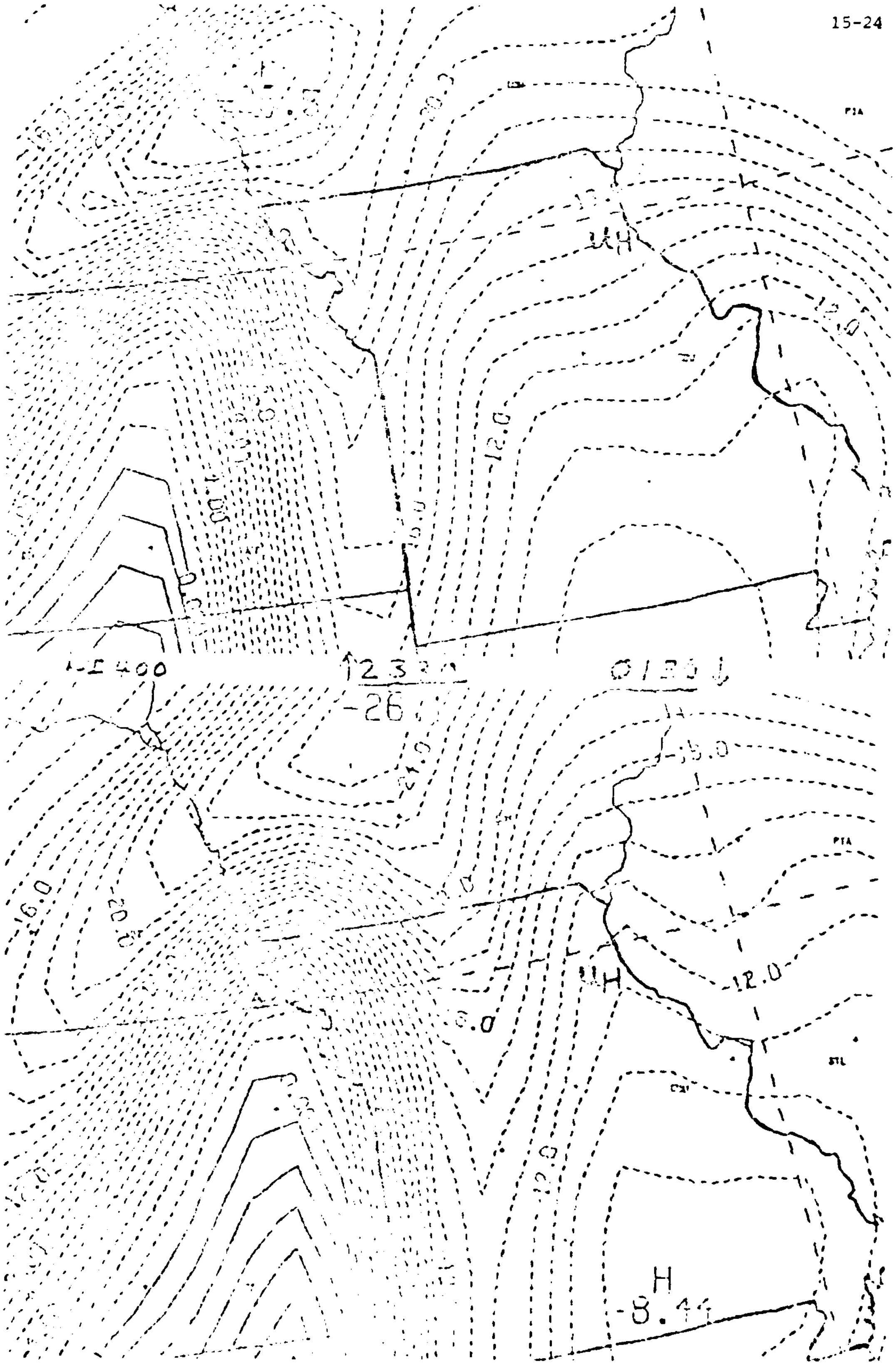
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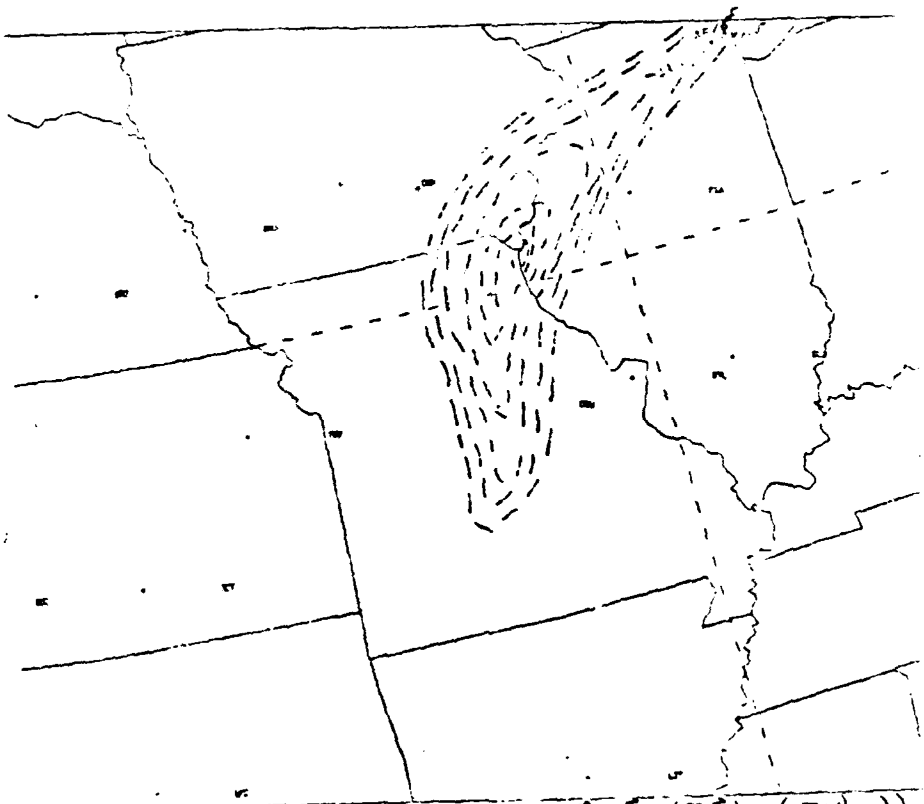
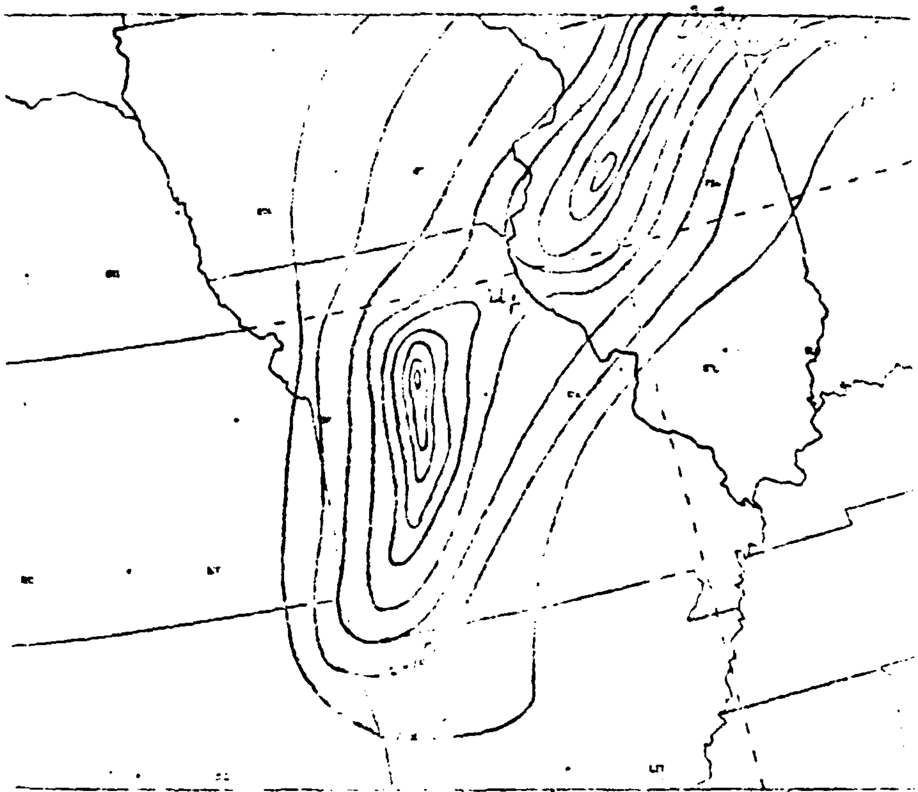
4) M.A.S.S. POTENTIAL UTILITY FOR C.A.T., WIND SHEAR, AND TURBULENCE HAZARDS FORECASTING



0230 GMT $\left\{ \frac{(-LI)(Rh)\,\vec{V}_{250}\,\vec{V}_{LVL1}\,(\nabla\cdot\vec{V})_{250}\,(-\nabla\cdot V)_{LVL1}}{(R_i)\,(\zeta+f)_{250}\,(\zeta+f)_{LVL1}} \right\}$ INDEX



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[illegible] R.A.S.S. (Chronolog[illegible])

p	[illegible]	[illegible]	[illegible]	[illegible]
	4500		7[illegible]	
	5000		78	
	5500	220°	82	
	6000	220°	87	
	6500		91	
	7000	230°	95	
400	7500		100	([illegible])
	8000		10[illegible]	
	[illegible]		108	
325	9000		112	(115)
	9500	240°	117	
	10000		121	
250	10500	250°	125	(150)
	11000		130	
	11500	245°	13[illegible]	
	12000		138	
	[illegible]	255°	1[illegible]	

Scorer, in his analysis of the stability of vortex layers, formulates a stability boundary in terms of a wave number k_c, where

$$k_c = 2g \frac{\rho_1 - \rho_2}{\rho_1 + \rho_2} \frac{1}{(\Delta U)^2}$$

ρ_1 = density at lower boundary of layer

ρ_2 = density at upper boundary of layer

g = gravitational constant

ΔU = change in wind speed across vortex layer

$\lambda_c = \frac{2\pi}{k_c}$ = critical wavelength

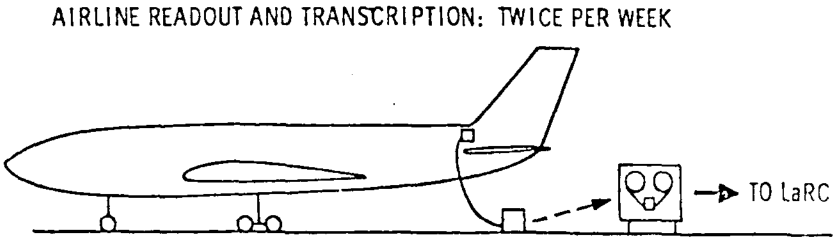
If [illegible] is produced at a wavelength λ and λ [illegible] will be unstable [illegible] the formation of cat's eyes [illegible].

FUTURE PLANS

1. CONTINUED MODEL DEVELOPMENT
2. CONTINUED EXPANSION OF APPLICATIONS SOFTWARE FOR 5 PROBLEM AREAS
3. EXPANSION OF ROLE IN SHUTTLE APPLICATIONS
4. EXPAND MODEL TO HEMISPHERIC COVERAGE AT MESOSCALE ON C.D.C. CYBER 205 IN MINNEAPOLIS
5. 40-DAY SPRING TEST AND GODDARD LABORATORY EVALUATION

DVGH PHASE II
SYSTEM DESIGN APPROACH

Work performed under LaRC Contract NAS1-16098
By RESEARCH TRIANGLE INSTITUTE


AIRLINE READOUT AND TRANSCRIPTION: TWICE PER WEEK
TO LaRC

AD-A136 364 REPORT ON A VISIT TO THE USA DURING JANUARY 1982 RELATING TO THE EFFECT O..(U) AERONAUTICAL RESEARCH LABS MELBOURNE (AUSTRALIA) D J SHERMAN AUG 82 3/3

UNCLASSIFIED ARL/STRUC-TM-344-SUPPL F/G 4/2 NL

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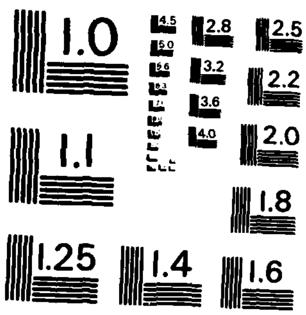
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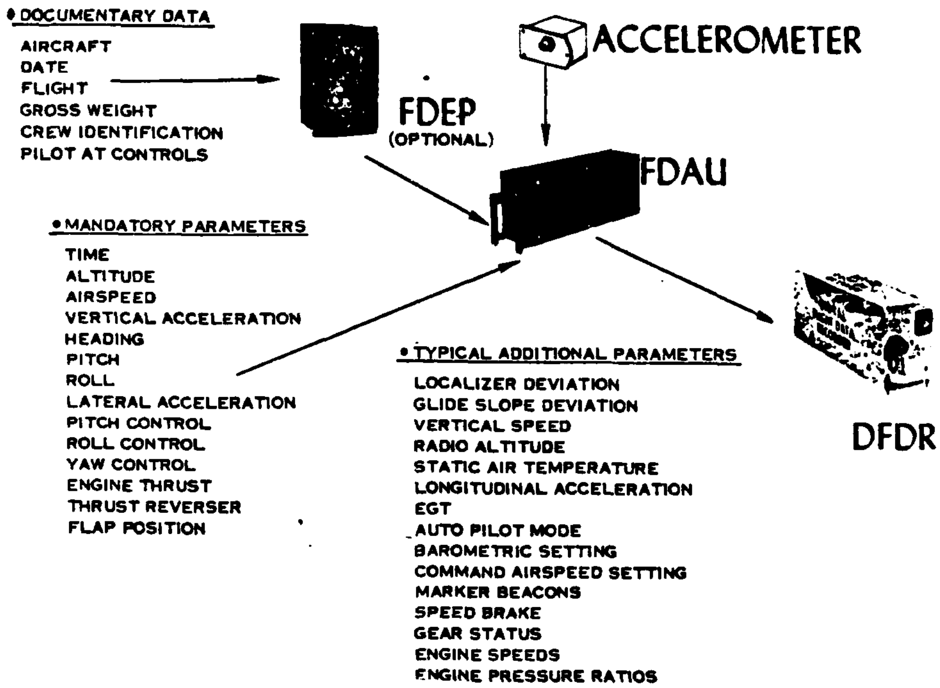
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FLIGHT
GROSS WEIGHT
CREW IDENTIFICATION
PILOT AT CONTROLS
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(OPTIONAL)
ACCELEROMETER
FDAU
• MANDATORY PARAMETERS
TIME
ALTITUDE
AIRSPEED
VERTICAL ACCELERATION
HEADING
PITCH
ROLL
LATERAL ACCELERATION
PITCH CONTROL
ROLL CONTROL
YAW CONTROL
ENGINE THRUST
THRUST REVERSER
FLAP POSITION
• TYPICAL ADDITIONAL PARAMETERS
LOCALIZER DEVIATION
GLIDE SLOPE DEVIATION
VERTICAL SPEED
RADIO ALTITUDE
STATIC AIR TEMPERATURE
LONGITUDINAL ACCELERATION
EGT
AUTO PILOT MODE
BAROMETRIC SETTING
COMMAND AIRSPEED SETTING
MARKER BEACONS
SPEED BRAKE
GEAR STATUS
ENGINE SPEEDS
ENGINE PRESSURE RATIOS
DFDR

31-31-22 Customer Specified Parameters

- Radio Altitude
- Groundspeed
- Localizer Deviation
- Glideslope Deviation
- True Heading
- True Track Angle
- Mach Number
- Angle of Attack
- Total Air Temperature
- Static Air Temperature
- ADC Discretes - TBD
- Baro Correction (Captain's)
- Inertial Vertical Velocity
- Present Latitude
- Present Longitude
- Windspeed
- Wind Angle
- Drift Angle
- N1 - L
- N1 - R
- N2 - L
- N2 - R
- N3 - L
- N3 - R
- EGT - L
- EGT - R
- Fuel Flow - L
- Fuel FLow - R
- Engine Vibration - L
- Engine Vibration - R
- Caution and Warning Discretes (TBD)
- Engine Oil Temperature L & R
- Engine Oil Pressure L & R
- Engine Oil Quantity L & R
- APU EGT and RPM
- Flight Path Angle

ADDED REV SYM D

STATEMENT OF WORK

- DESIGN AND IMPLEMENT A NASA TEST SYSTEM FOR USE IN IDENTIFYING THE NOISE ENVIRONMENT AND IN ISOLATING SOURCES OF DATA ANOMALIES IN THE AIRLINE DIGITAL DATA.

- ANALYZE AND COMPARE AIRLINE DIGITAL DATA TO THE DATA OBTAINED USING THE NASA SYSTEM. ASCERTAIN THE SOURCE OF THE DATA ANOMALIES.

- AUTOMATE THE TECHNIQUES USED IN THE MANUAL REMOVAL OF THE ANOMALIES ON GROUND-BASED COMPUTERS.

- DESIGN STATISTICAL DATA REDUCTION TECHNIQUES AND IMPLEMENT ON GROUND-BASED COMPUTERS.

- DESIGN OF AN ON BOARD STATISTICAL DATA PROCESSOR/RECORDER FOR USE IN THE DIGITAL VGH PROGRAM.

DVGH PHASE II REQUIREMENTS

BRANCH LETTER SAME SUBJECT DATED DEC. 17, 1979

SPECIFIC

- TABULATE LEVEL CROSSINGS FOR SPECIFIC ALT BANDS
  7 TABLES × 9 alt. bands.
- MINI-MAX ACCELERATION & GUSTS
  5 TABLES
- FLIGHT PROFILE STATISTICS
  7 TABLES
- WEIGHT & ALTITUDE STATISTICS
  2 TABLES
- AIRSPEED & ALTITUDE
  3 TABLES

TOTAL 24 TABLES

~ 5100 ENTRIES

IMPLIED

- 250 FLIGHT HOURS
- ARINC 573
- CAS DATA 1/SEC
- VERG DATA 4/SEC
- LATG DATA 4/SEC
- ALT DATA 1/SEC
- GROSS WEIGHT AT TAKEOFF
  1 PER FLIGHT
- MAINGEARSW 1/SEC
- AUTOPILOTSW 1/SEC
- FLIGHT TYPE
- SEPARATE GUST & MANEUVER ACCELERATIONS
- AIRCRAFT CHARACTERISTICS
  WING AREA
  LIFT CURVE SLOPE
  RATE OF FUEL BURN
- ATMOSPHERIC TABLE DATA
- DATA TRUTH
- FUEL USE RATE

DVGH PHASE II FUNDAMENTAL REQUIREMENTS

DATA ACQUISITION AND PROCESSING

- RELIABLE AND ACCURATE DATA SOURCE
- ASSESSABLE DATA INTEGRITY
- REASONABLE PROCESSING AND MEMORY REQUIREMENTS

DIAGNOSTIC TESTS

- LARC LABORATORY TEST BED
  - AIRCRAFT SENSORS, DIGITAL ELECTRONICS, AND CRASH RECORDERS TESTED
    - NOMINAL AND WORSE CASE
    - ALL MANUFACTURERS
- FLIGHT TEST
  - NASA DIAGNOSTIC RECORDING SYSTEM FLOWN IN PARALLEL WITH ARINC 573
    - SYSTEM IN COMMERCIAL OPERATION >40 HRS
- RESULTS
  - -ARINC 573 DIGITAL DATA STREAM IS AN EXCELLENT SOURCE OF DVGH PHASE II DATA
  - -CRASH RECORDERS ARE NOT HIGH QUALITY VOLUME SOURCES OF DATA

SYSTEM DESIGN

(IN PARALLEL WITH DIAGNOSTIC TESTS)

- PERMANENT MEMORY REQUIREMENT

  $<64 \times 10^3$ BIT TO 1×10^9 BIT

- PROCESSOR CAPABILITY

  ALL FUNCTIONS; DECOMMUTATION, EDITING, FILTERING, COMPUTING AND STORAGE CAN BE ACCOMPLISHED IN REAL TIME

RESULTS

AIRBORNE DATA PROCESSING FEASIBLE

Airborne Digital VGH System Design

TASKS

Hardware

- Basic System Layout
- Memory Requirements
- Computational Speed Requirements
- Short Term Storage Requirements
- Long Term Storage Requirements
- Available Options for Each Function
- Cost Analysis
- Final System Configuration

Software

- System Supervisor
- Operational Modes
- Auxiliary Flight Data Entry
- Non-FDAU Data Entry
- Front-End Processing } Shutdown/Continue
- Data Editing } Shutdown/Continue
- Complementary Filtering
- Gust Velocity Determination
- Per-Flight Tabulations
- Across Flight Tabulations
- Data Storage

PROCESSOR DEVELOPMENT

- EDIT, FILTER, CALCULATION, FLIGHT MODE AND TABLE DERIVATION PROGRAMS WRITTEN AND ITERATED

- DATA PROCESSOR STRATEGY TESTED AT RTI AGAINST A 10 FLIGHT SAMPLE OF ACTUAL DATA

VERG-1 LEVEL CROSSINGS PER HOUR WITHIN PRESSURE ALTITUDE BANDS

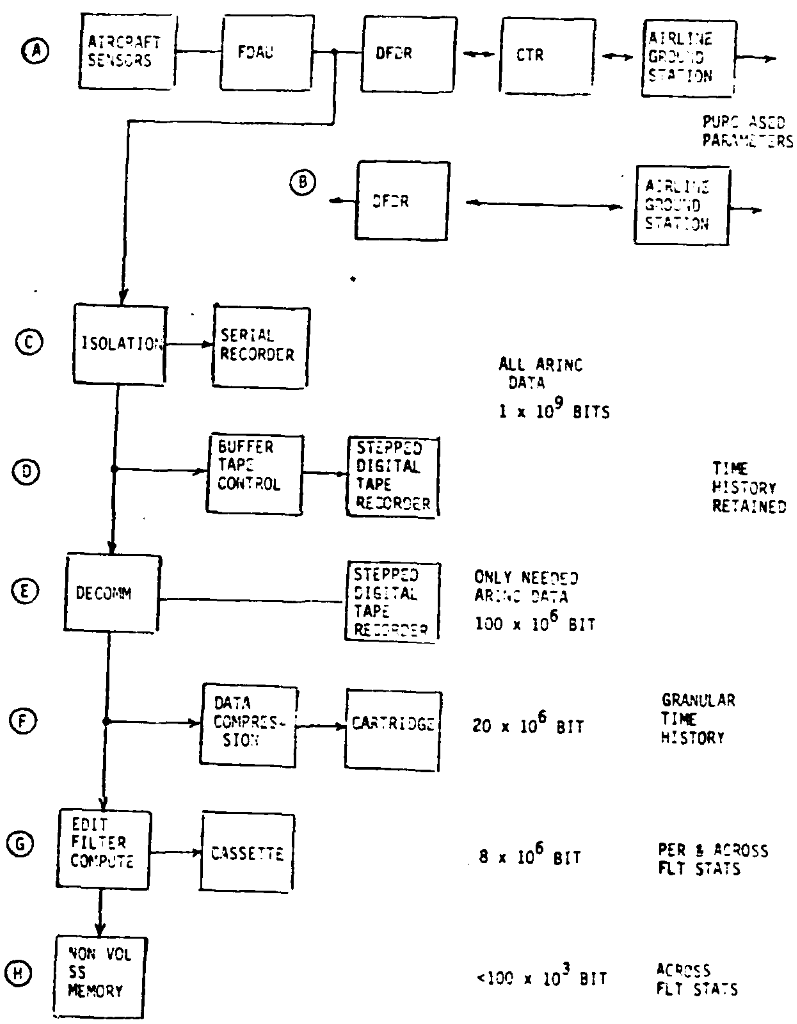
G UNITS	-500 TO 4500 (FT)	4500 TO 9500 (FT)	9500 TO 14500 (FT)	14500 TO 19500 (FT)	19500 TO 24500 (FT)	24500 TO 29500 (FT)	29500 TO 34500 (FT)	34500 TO 39500 (FT)	39500 TO 44500 (FT)
1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.40	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.30	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.20	11.04	5.92	3.35	1.09	0.00	0.00	0.00	0.36	0.00
0.15	40.72	20.29	6.71	3.20	0.00	0.00	0.42	2.41	0.00
0.10	131.13	101.43	36.89	26.22	6.92	2.15	5.93	11.82	0.00
0.05	295.40	195.26	151.75	140.59	66.20	53.29	57.59	59.04	0.00
0.00	775.77	640.71	847.60	759.33	701.75	1317.70	1167.11	1027.12	0.00
-0.05	209.00	105.96	155.94	192.29	90.02	96.09	80.51	129.45	0.00
-0.10	55.21	35.50	39.40	24.04	6.92	3.23	8.47	14.72	0.00
-0.15	15.10	5.92	13.41	17.40	0.00	0.00	2.96	3.62	0.00
-0.20	1.30	0.85	6.71	7.65	0.00	0.00	2.54	0.04	0.00
-0.30	0.69	0.00	3.35	1.09	0.00	0.00	0.00	0.00	0.00
-0.40	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FLIGHT HRS @ ALT	1.45	1.10	1.19	0.92	1.01	1.86	2.36	8.29	0.00
FLIGHT MILES	322.2	356.3	464.7	417.4	501.7	1027.7	1352.7	4787.2	0.0

TOTAL FLIGHTS	10
TOTAL FLIGHT HOURS	18.3
TOTAL FLIGHT MILES	9230.9

RESULTS OF 10 FLIGHT COMPARISON

- AUTOMATIC FLIGHT MODE SEPARATION ALGORITHMS MATCH TIME HISTORIES
- TABLES GENERATED & MATCH <3% AVG.
- EDIT AND FILTERING PROGRAMS OPERATIONAL

DVGH PHASE II SYSTEM OPTIONS



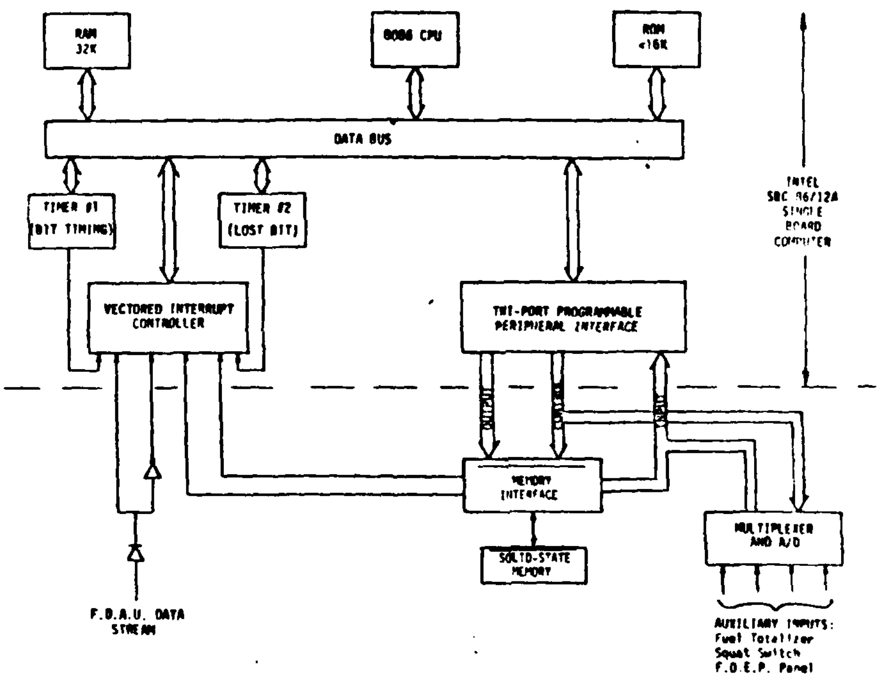
RECOMMENDATION FOR DVGH PHASE II SYSTEM DESIGN

ON-BOARD DATA COLLECTION PROCESSING STORAGE USING MICROCOMPUTER WITH ARINC 573 DATA STREAM SOURCE

DIRECTION

NASA DESIGN REVIEW RECOMMENDED EMPHASIS ON MAXIMUM DATA INTEGRITY

- SOLID-STATE TECHNOLOGY HIGHEST QUALITY STORAGE MEDIA
- BUILT IN TEST



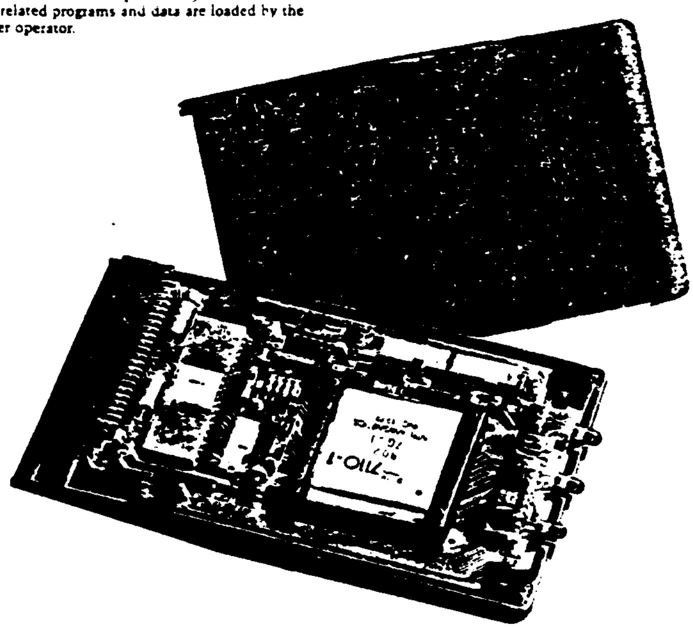
SYSTEM HARDWARE CONFIGURATION

NEW PLUG-A-BUBBLE SYSTEM PROVIDES COMPACT CASSETTE STORAGE FOR HARSH ENVIRONMENTS

THE PLUG-A-BUBBLE SYSTEM [illegible] featuring [illegible] removable bubble cassettes is designed to provide portable, compact, permanent memory storage in harsh environments or critical storage applications. The basic iPAB system consists of a 128K-byte capacity bubble memory cassette and holder. It is ideal in environments that include temperature extremes, changes in air pressure and humidity, poor air quality, vibration, shock, or risk of power loss.

Users involved with test instrumentation, telecommunications and data acquisition terminals, and in industrial machine or process control will find the Plug-A-Bubble system particularly advantageous because of its easy portability. The system excels in situations that include handling or transportation, e.g. to and from a central processing center or where process-related programs and data are loaded by the computer operator.

The Plug-A-Bubble cassette is housed in a rugged cast aluminum cartridge. It contains Intel's 7110 1-megabit bubble memory component, the 7220 controller, the 7230 current pulse generator, the 7242 dual formatter/sense amplifier, a 7250 coil predriver, and [illegible] 7254 quad [illegible] transistors. All are mounted on a printed circuit board and packaged within the sealed cartridge. The cartridge also has a "write protect" switch which can be used to prevent accidental overwriting of the cassette. Data is transferred at transistor-transistor logic (TTL) levels between the cassette and holder.



The Plug-A-Bubble memory system features removable [illegible] to provide compact permanent [illegible]

206

DESCRIPTION

PHYSICAL

SIZE	1/2 ATR CASE 13" x 7.625" x 4.875"
WEIGHT	4.5#

ELECTRICAL

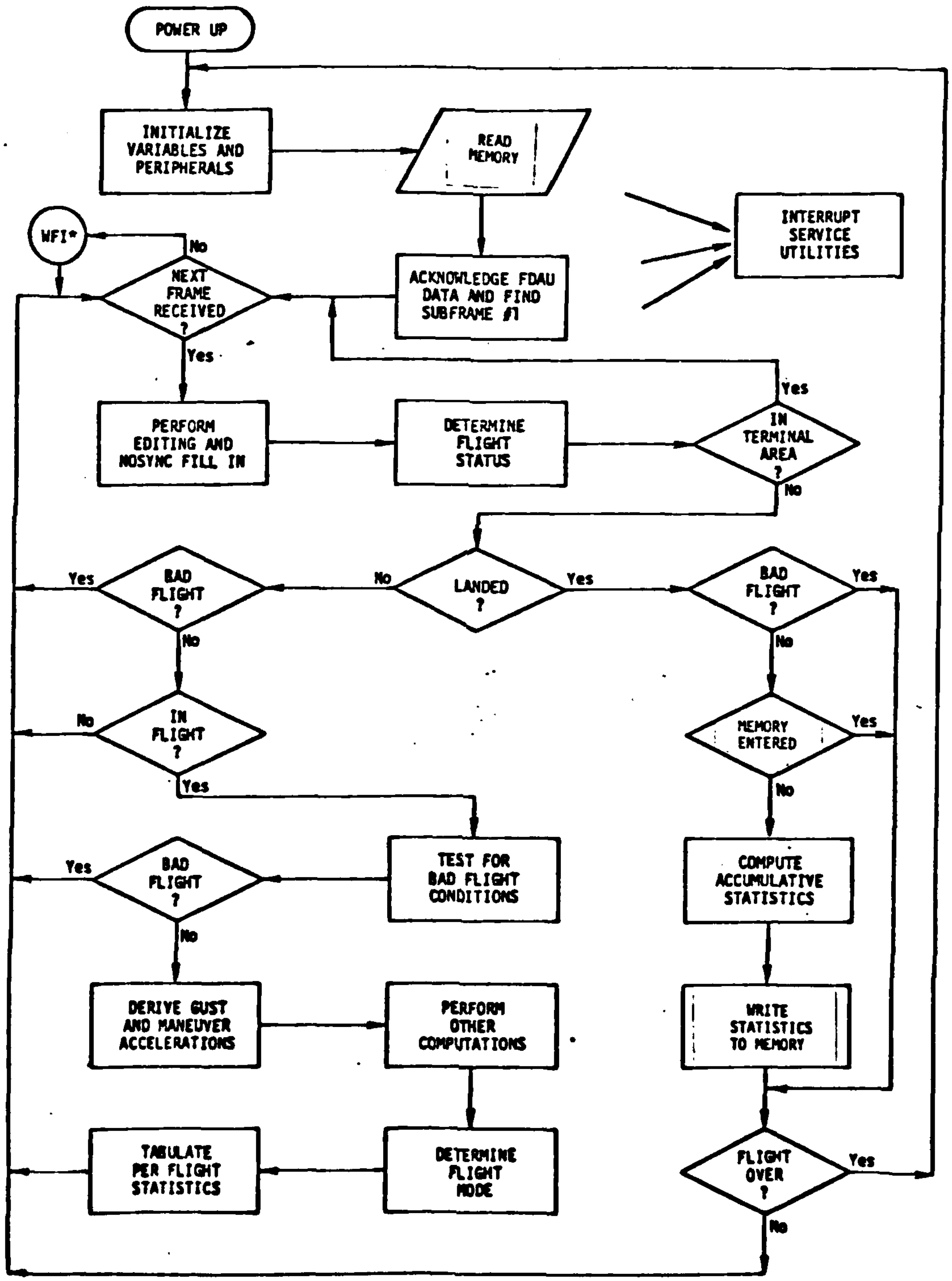
POWER	24W

PROPOSED PROGRAM STRUCTURE

- DVGH
  - INITIALIZE
    - CHECK STATUS
    - READ INTERNAL MEMORY
    - READ PERM MEMORY
      - BUILT IN TEST
  - LOCK ON DATA STREAM
  - PER FLIGHT
    - FRAME
      - CONVERT
      - BIAS
    - EDIT
      - EDIT
    - AIRCRAFT STATUS
    - EDIT
    - FILTER
    - GUST VELOCITY
    - FLIGHT MODE
    - FLIGHT STATUS
  - ACCESS MEMORY
    - WRITE MEMORY
      - CHECK MEMORY
  - INTERRUPT SERVICE FACILITIES

INTERRUPTS FROM ARINC 573 DATA ACKNOWLEDGED DURING THIS TIME

GENERAL FLOW DIAGRAM



*Wait for Interrupt

RECOMMENDATIONS FOR DVGH PHASE II PROGRAM DIRECTION

<u>DEVELOPMENT</u>

PROTOTYPE FABRICATION AND FLIGHT TEST

VERIFY ALL OPERATIONAL DESIGN FEATURES IN AIRLINE ENVIRONMENT

- ~1 YR
- FLTS OCT. 82

<u>IMPLEMENTATION</u>

DEPLOY DVGH PROCESSORS IN LARGE COMMERCIAL FLEET

- START 4TH QTR. 82
- DEPLOY 10 BY 83

<u>EXPAND TO INCLUDE</u>

G-A
COMMUTER

MAINTENANCE

SUMMARY OF DVGH PHASE II CONTRACT

- THE ARINC 573 DATA STREAM VALID SOURCE OF VGH INFORMATION
- DATA ACQUISITION, EDITING, AND COMPUTATIONAL TASKS WITHIN THE CAPABILITIES OF MICROCOMPUTER
- DVGH PHASE II DESIGN HAS BEEN ESTABLISHED
- A PROTOTYPE VALIDATION PROGRAM IS PROPOSED
- COSTING AND SCHEDULING OF AN OPERATIONAL SYSTEM ESTIMATED

END

DATE
FILMED

1-84

DTIC